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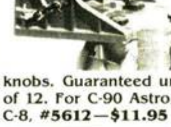

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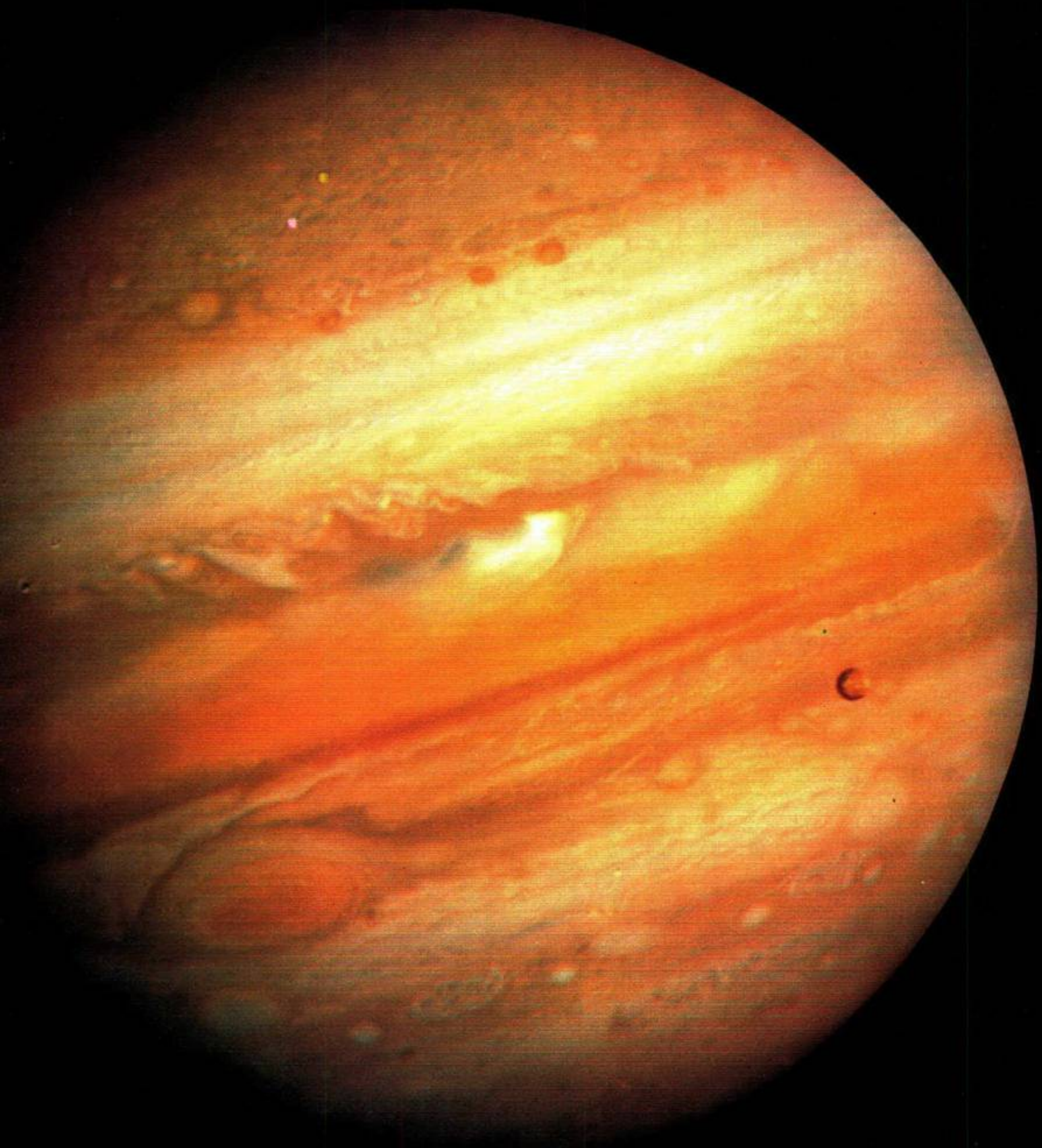

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Cover: Four new worlds circle the planet Jupiter, worlds that are as distinctly different from one another as they are from the well-explored planets of the inner solar system. This month, ASTRONOMY takes you to those worlds with astronomer/author David Morrison and an album of the best available spacecraft photographs from NASA and JPL. These pages: Voyager 1 photographed Jupiter and three of its satellites. Io lies in front of the planet, its color golden brown. Europa, to the right, shines a brilliant icy white. Callisto's surface is mottled and dark. NASA/JPL photograph. Cover painting by Carl Chaplin.

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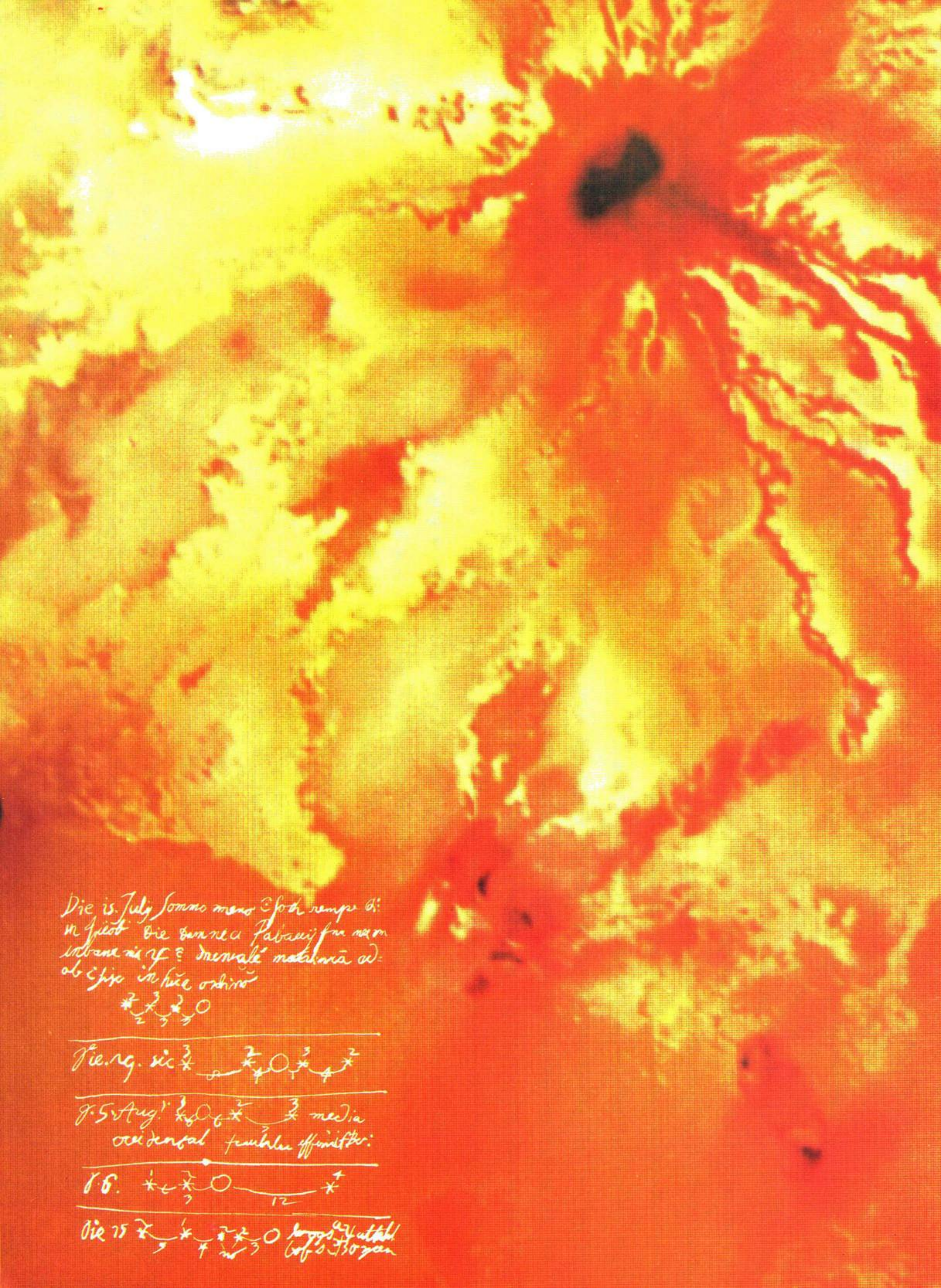
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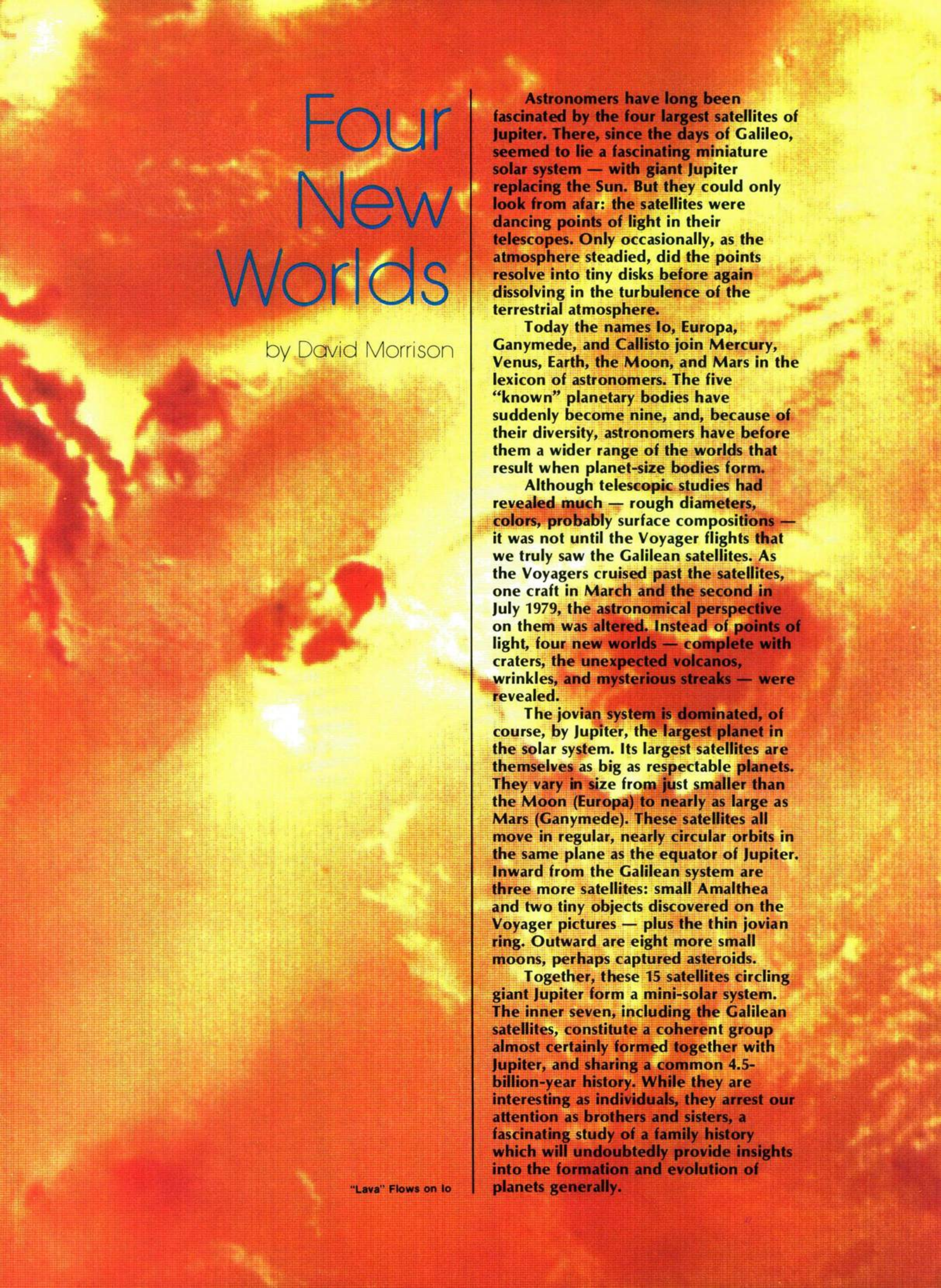
Four New Worlds

by David Morrison



"Lava" Flows on Io

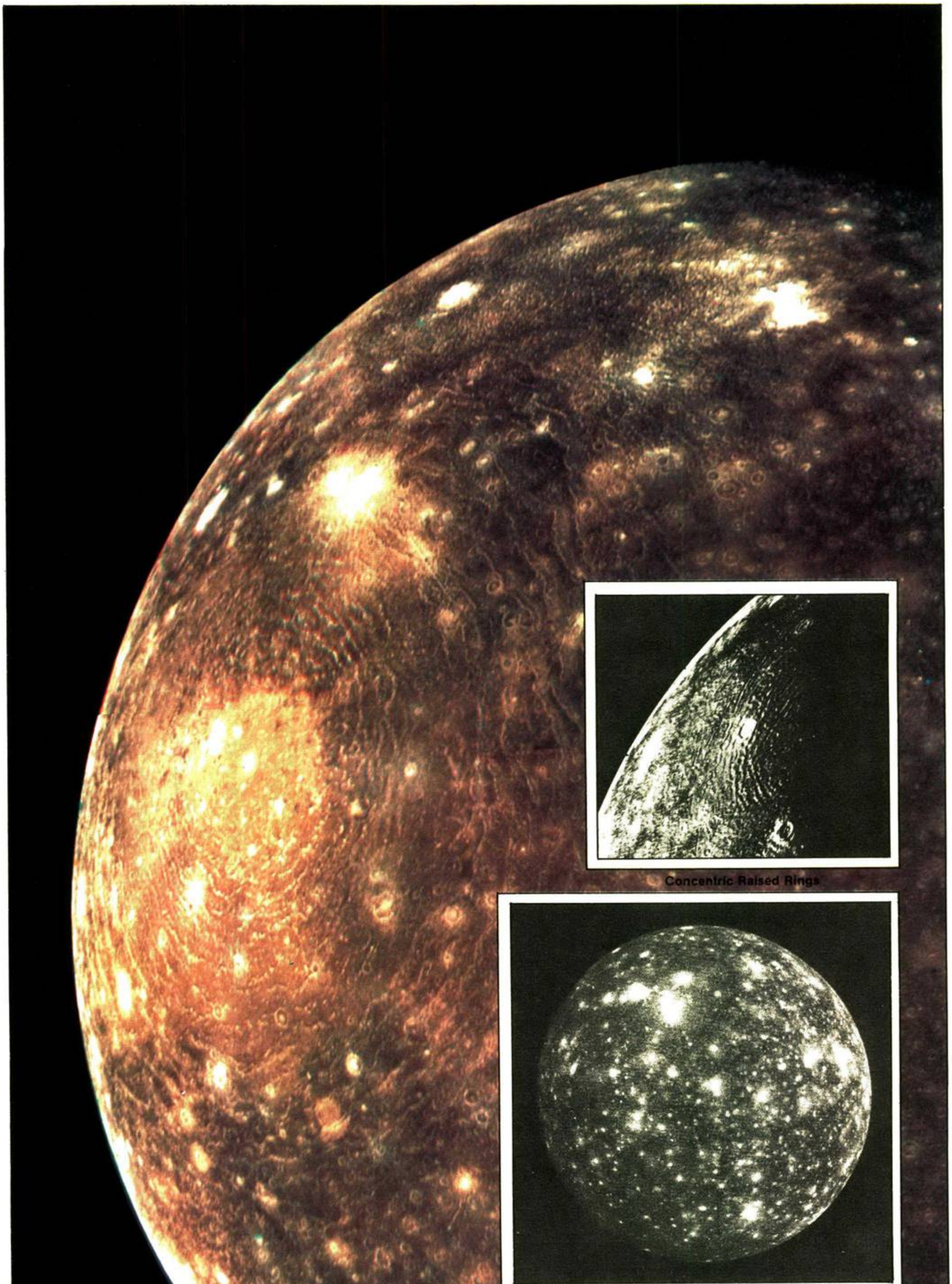
Astronomers have long been fascinated by the four largest satellites of Jupiter. There, since the days of Galileo, seemed to lie a fascinating miniature solar system — with giant Jupiter replacing the Sun. But they could only look from afar: the satellites were dancing points of light in their telescopes. Only occasionally, as the atmosphere steadied, did the points resolve into tiny disks before again dissolving in the turbulence of the terrestrial atmosphere.

Today the names Io, Europa, Ganymede, and Callisto join Mercury, Venus, Earth, the Moon, and Mars in the lexicon of astronomers. The five "known" planetary bodies have suddenly become nine, and, because of their diversity, astronomers have before them a wider range of the worlds that result when planet-size bodies form.

Although telescopic studies had revealed much — rough diameters, colors, probably surface compositions — it was not until the Voyager flights that we truly saw the Galilean satellites. As the Voyagers cruised past the satellites, one craft in March and the second in July 1979, the astronomical perspective on them was altered. Instead of points of light, four new worlds — complete with craters, the unexpected volcanos, wrinkles, and mysterious streaks — were revealed.

The jovian system is dominated, of course, by Jupiter, the largest planet in the solar system. Its largest satellites are themselves as big as respectable planets. They vary in size from just smaller than the Moon (Europa) to nearly as large as Mars (Ganymede). These satellites all move in regular, nearly circular orbits in the same plane as the equator of Jupiter. Inward from the Galilean system are three more satellites: small Amalthea and two tiny objects discovered on the Voyager pictures — plus the thin jovian ring. Outward are eight more small moons, perhaps captured asteroids.

Together, these 15 satellites circling giant Jupiter form a mini-solar system. The inner seven, including the Galilean satellites, constitute a coherent group almost certainly formed together with Jupiter, and sharing a common 4.5-billion-year history. While they are interesting as individuals, they arrest our attention as brothers and sisters, a fascinating study of a family history which will undoubtedly provide insights into the formation and evolution of planets generally.



Concentric Raised Rings

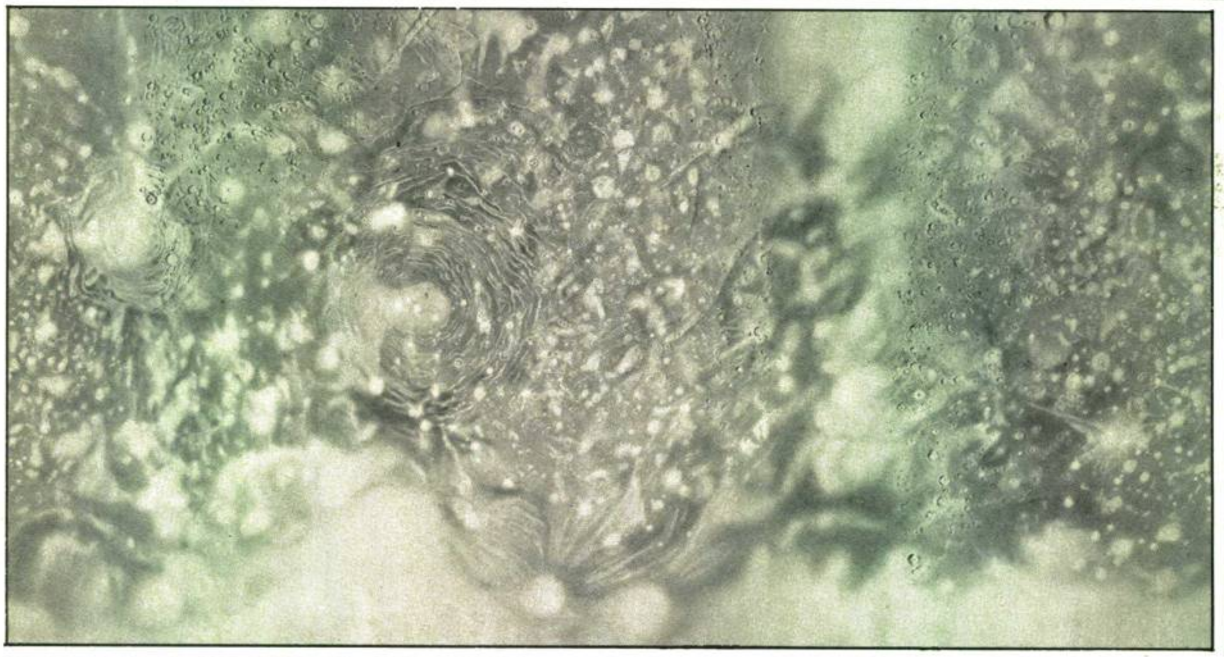
Saturation Cratering

The Icy Worlds: Callisto and Ganymede

Callisto and Ganymede, the outer two Galilean satellites, present a striking contrast to the inner pair, Europa and Io. Well before the Voyager flybys, groundbased astronomers knew there was some kind of fundamental difference — for Callisto and Ganymede have a markedly lower density than the inner pair or any of the terrestrial planets. The low density implies a partially icy composition, as opposed to the largely rocky materials expected for Europa and Io, or rock and metal as Earth, its Moon, and the other terrestrial planets have. If anything, planetary astronomers expected the outer two to be quite strange.

Who, indeed, could guess how a world made of ice would behave? Voyager began to provide an answer to that question.

Callisto



Callisto, the least geologically active of the Galilean satellites, is basically a dead world. With virtually no sign of major internal activity, it still bears the scars of the innumerable meteoric impacts it received early in the life of the solar system, as well as immense "ghost" impact basins.

On Callisto the number of craters is very great. In some places they are packed so closely that more impacts don't add to the overall number — they just eradicate other craters. Although no one knows the exact rate of formation of impact craters on the jovian satellites, geologists on the Voyager Imaging Team estimate that it would require about several billion years to accumulate this many craters. There seems to be nothing on Callisto that has removed, erased, or filled craters in. They conclude, therefore, that Callisto has been geologically inactive since near the time of its formation.

We who live on Earth tend to forget, or fail to realize, the importance of cratering. Our planet has very few craters, and those that we do see are frequently volcanic rather than meteoric. Are we favored — does an "invisible shield" protect us from the cosmic shooting gallery? No; in fact, careful searches of old rocks show Earth has experienced as many impacts as has the Moon and other planets. Craters, though formed as often, are soon eradicated by the geological activity of Earth — erosion, volcanism, mountain-building, continental drift, and sedimentation.

Even though, on the average, a ten-kilometer wide crater is formed on Earth about once every million years, all those older than a few million years have been eroded away, filled in, or crushed beyond recognition by crustal motion. However, on a planet lacking internal geologic forces, such as our Moon, craters can survive almost indefinitely.

The higher the number of craters in a particular area (i.e., the greater its "crater density"), the older an area is likely to be. In fact, crater density is the first thing a planetologist looks at when he sees a planet for the first time: the craters are crucial — revealing internal activity or the lack of it. For more advanced planetary studies, they help in unraveling the planet's history.

Analysis of Voyager images provided an improved diameter for Callisto of 4840 km, yielding an average density of 1.8 grams per cubic centimeter. It is primarily the low density that leads astronomers to the conclusion that ice or water is an important component of the interior of Callisto. By itself, rock typically has a density of about 3.0 grams per cubic centimeter. But if an object were composed half of rock and half of ice (which has a density of 1.0

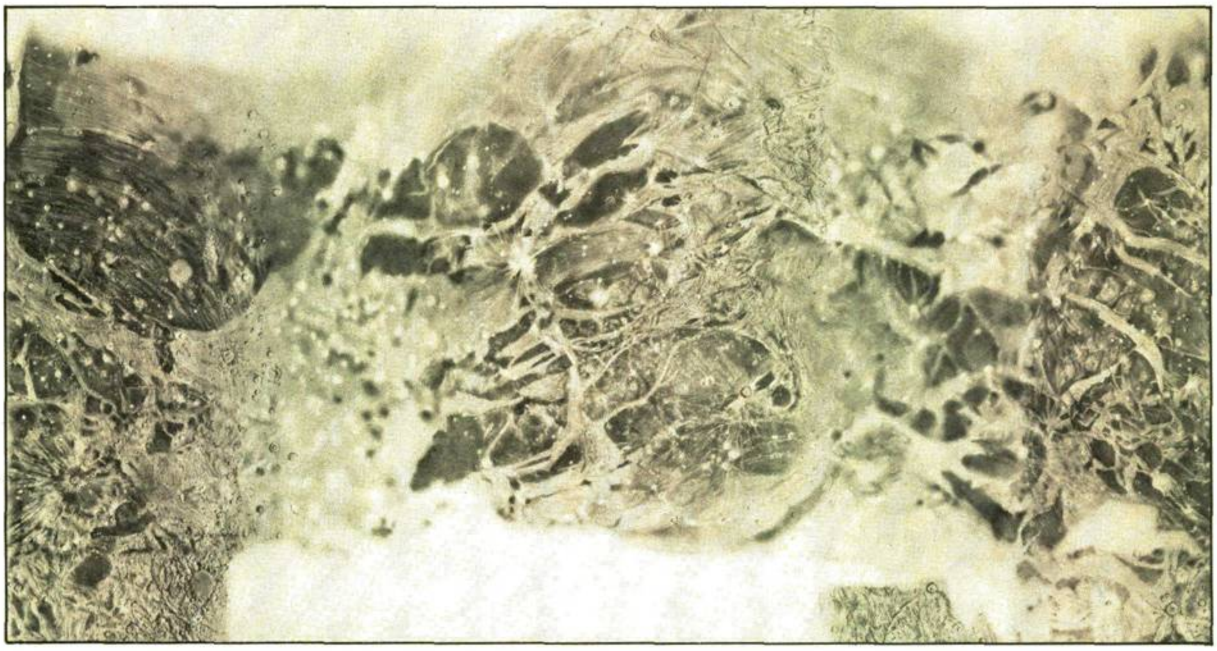
gm/cm³, the average would be 2.0, close to the value observed for Callisto. Although the ice has never been detected directly, the peculiar nature of the craters seen by Voyager adds strong circumstantial support to this conclusion.

Although it looks superficially similar to the heavily-cratered surfaces of the Moon and Mercury, Callisto is far from identical to these rocky worlds. One of the most obvious differences is the lack of craters larger than about 150 km, together with a tendency for moderately large craters to be quite shallow. Apparently, the ice-rock composition of Callisto alters the ability of the crust to retain large craters. Over many millions of years, geologists speculate, the ice flows, filling in crater floors and gradually obliterating the largest craters. There is also a conspicuous absence of mountains on Callisto, again suggestive of a weak crust.

Prominent in the Voyager pictures are the ghost remnants of what must once have been immense impact basins. The largest of the three discovered, the "bull's-eye" of the Voyager 1 images, has been named Valhalla, for the home of the Norse gods. These giant ghost basins have lost nearly all of their vertical relief. What remains is a central, light-colored zone (probably the location of the original crater), surrounded by numerous concentric rings of subdued bright ridges. Such features had never been seen before on any planet, but they appear to be characteristic geologic features on an ice-rock planet.

Little is known about the composition of the actual surface of Callisto, the material from which sunlight is reflected. It appears to be primarily dark rock or soil, but lacks diagnostic spectral features except for one infrared band caused by water ice covering a few percent of the exposed surface. The many lighter spots and arcs that outline craters in the high-resolution pictures may be regions where the ice is showing through, but these cover only a very small fraction of the surface.

With its heavily cratered surface, Callisto is certainly the most familiar-looking of the Galilean satellites. In fact, it's familiar enough that if all of the Galilean satellites had turned out to be as geologically dead as Callisto, planetary geologists would have been deeply disappointed. But as it has turned out, we know that these is no danger of disappointment: progressing inward toward Jupiter, each successive satellite shows the marks of increasing internal activity.



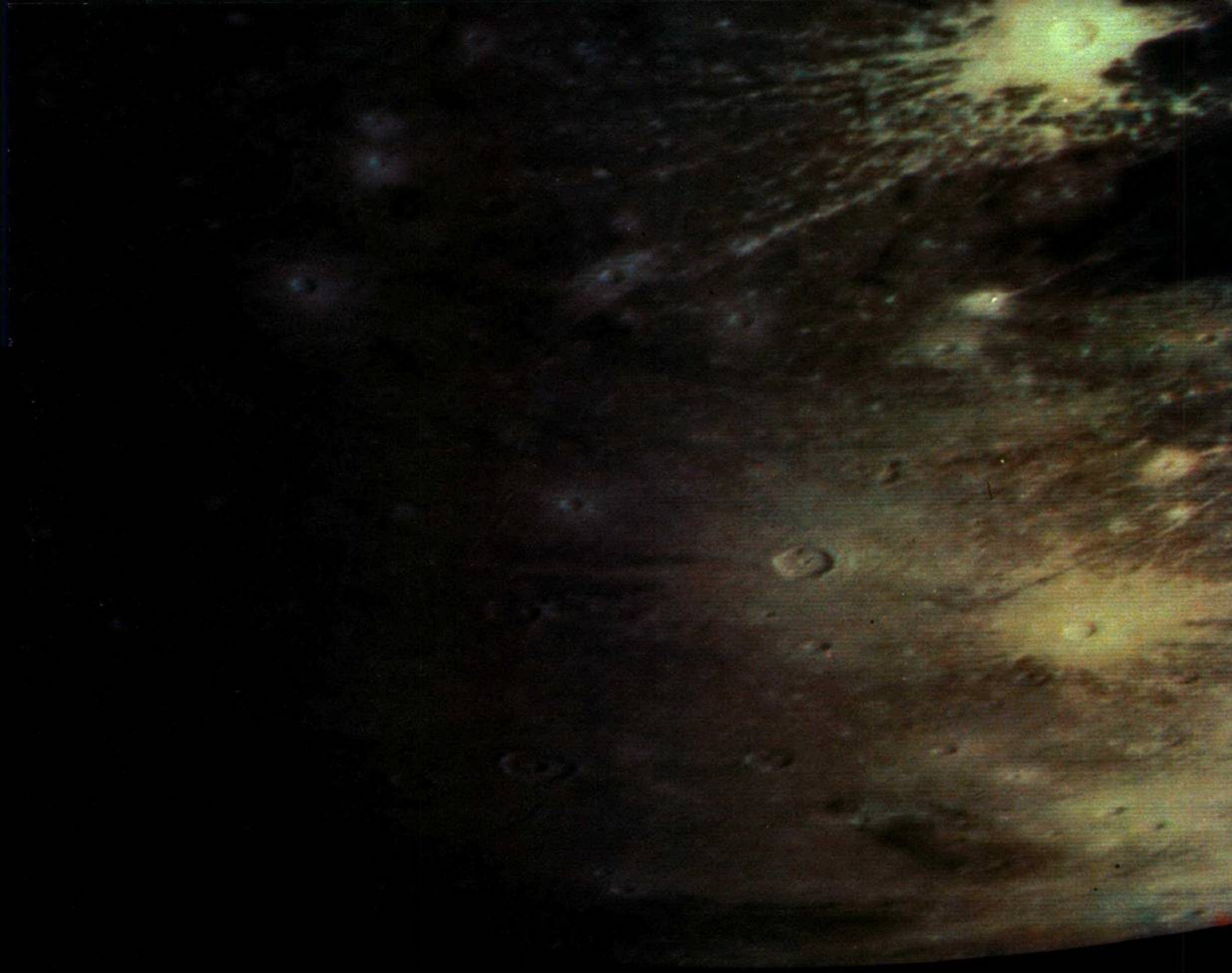
Ganymede

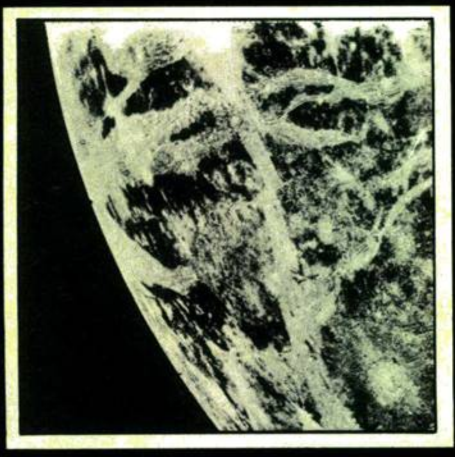
Before the Voyager mission, Ganymede was expected to be similar to Callisto. Ganymede shares Callisto's low density. For Ganymede, the value determined by Voyager (1.9 grams per cubic centimeter) indicates a bulk composition of about half rocky materials and half water. In addition, their diameters differ by only 8% (Ganymede is the larger of the two and the largest Jovian satellite), and both are far enough from Jupiter to escape the severe pounding Io receives from magnetospheric charged particles. It was therefore with great interest that Voyager scientists looked at the differences that emerged between these two satellites.

The surface of Ganymede is diverse. Unlike Callisto, Ganymede has undergone periods of geologic activity. There are, for example, numerous dark areas that resemble the surface of Callisto in both albedo (reflectivity) and number of craters. The largest of these, Regio Galileo, is 4000 km across — nearly as large as the continental United States.

This ancient terrain even preserves the remnants of a Callisto-type impact basin. Across Regio Galileo lies a system of subdued curving ridges like those surrounding Valhalla in Callisto. The center of this great system of arcs is missing, the ghost basin presumably destroyed by subsequent geologic activity.

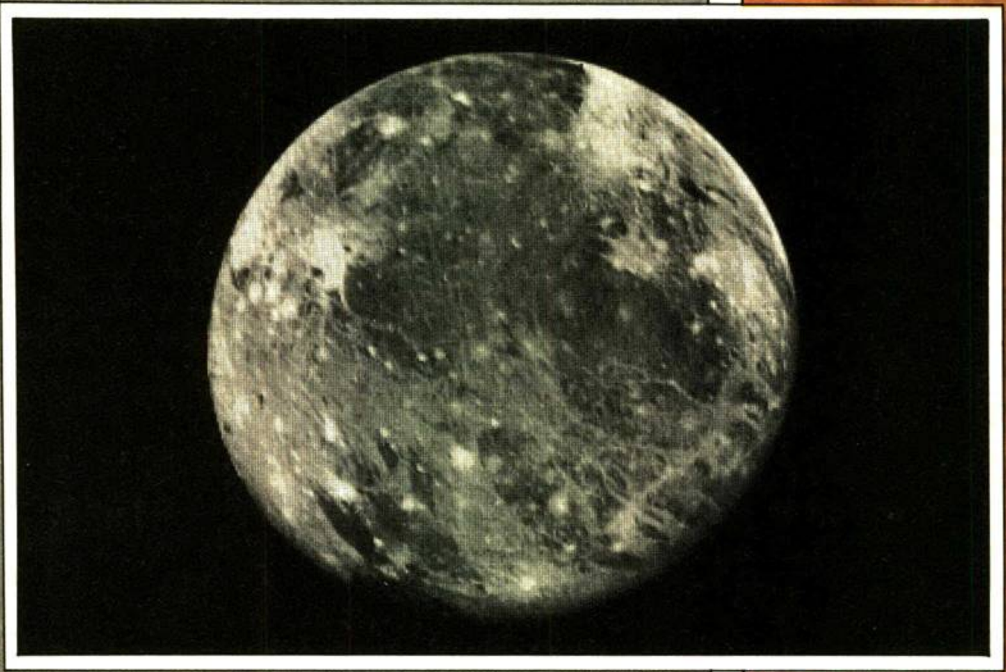
Other regions of the surface of Ganymede are clearly the product of intense, internal geologic activity. Generally, these regions are lighter in tone



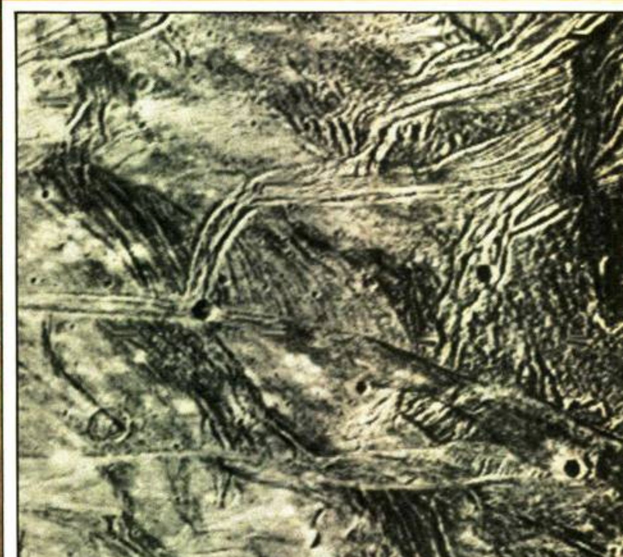


(that is, they have higher albedo). Their surface consists of many straight, parallel lines of mountains and valleys. Because of their appearance in the Voyager pictures, the Voyager geologists call these "grooved terrain." This name fails to convey their sheer size: these are mountains! Typically, they are 10 to 15 km across and about a kilometer high — similar in scale to sections of the Appalachian Mountains in the Eastern United States.

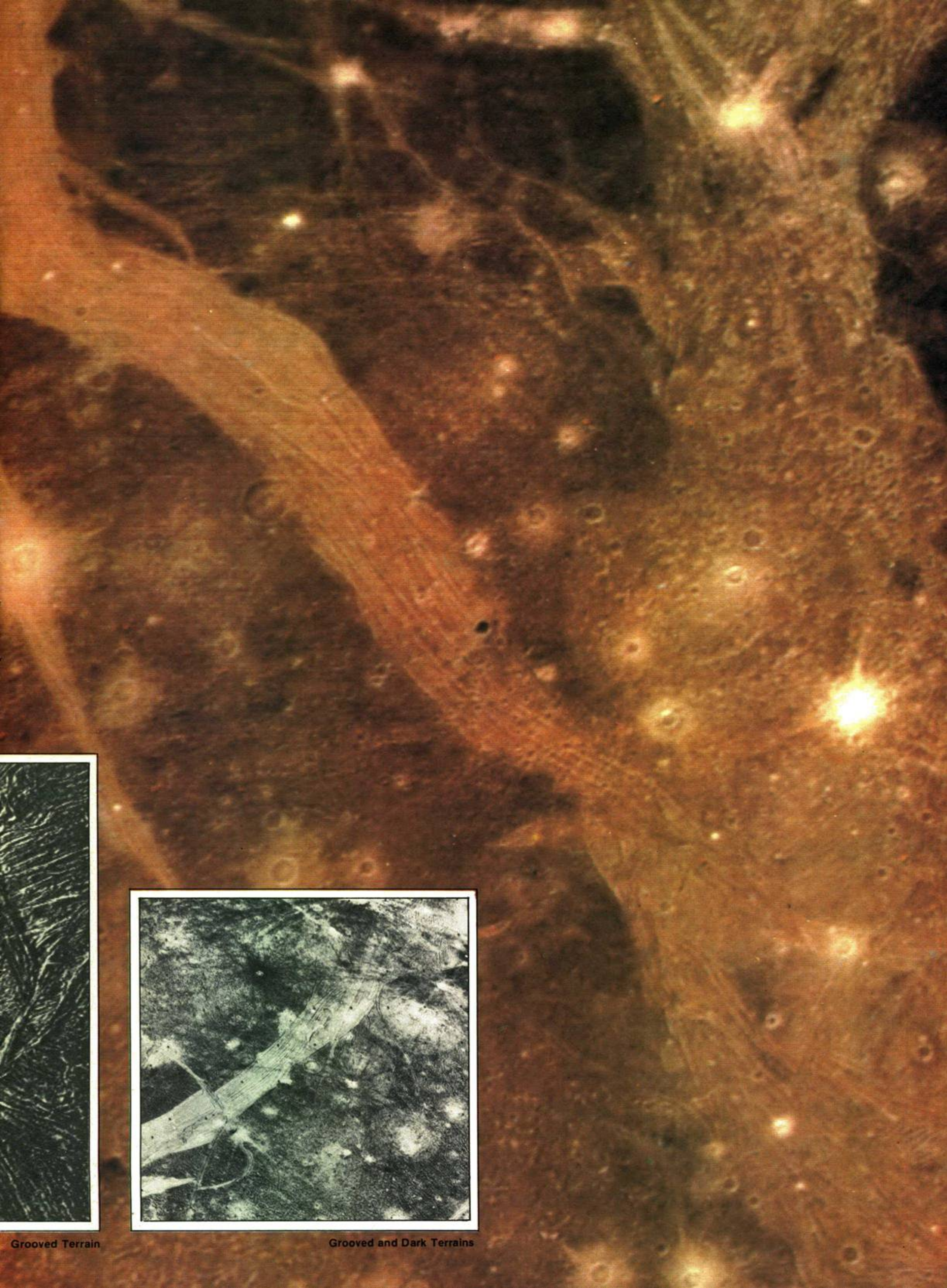
In many places the grooved terrain forms between areas of the older, darker surface, giving the appearance of mountains extruded between separating plates of ancient crust. But in other areas the relationships are much more complex, with curved systems of grooves and ridges overlying each other. Apparently, Ganymede has experienced not one, but a series of mountain building events.



The grooved terrains show a broad range in age, according to how heavily they are cratered. The oldest have nearly as many craters as the ancient dark plains. Their formation must have begun early, perhaps as long as four billion years ago. The youngest grooved terrain has only about one tenth as many craters, but this is still as many as we see in the 3.5 billion-year-old plains of our Moon. Thus the Voyager geologists suspect that even in these youngest areas, the geologic activity ceased billions of years ago.

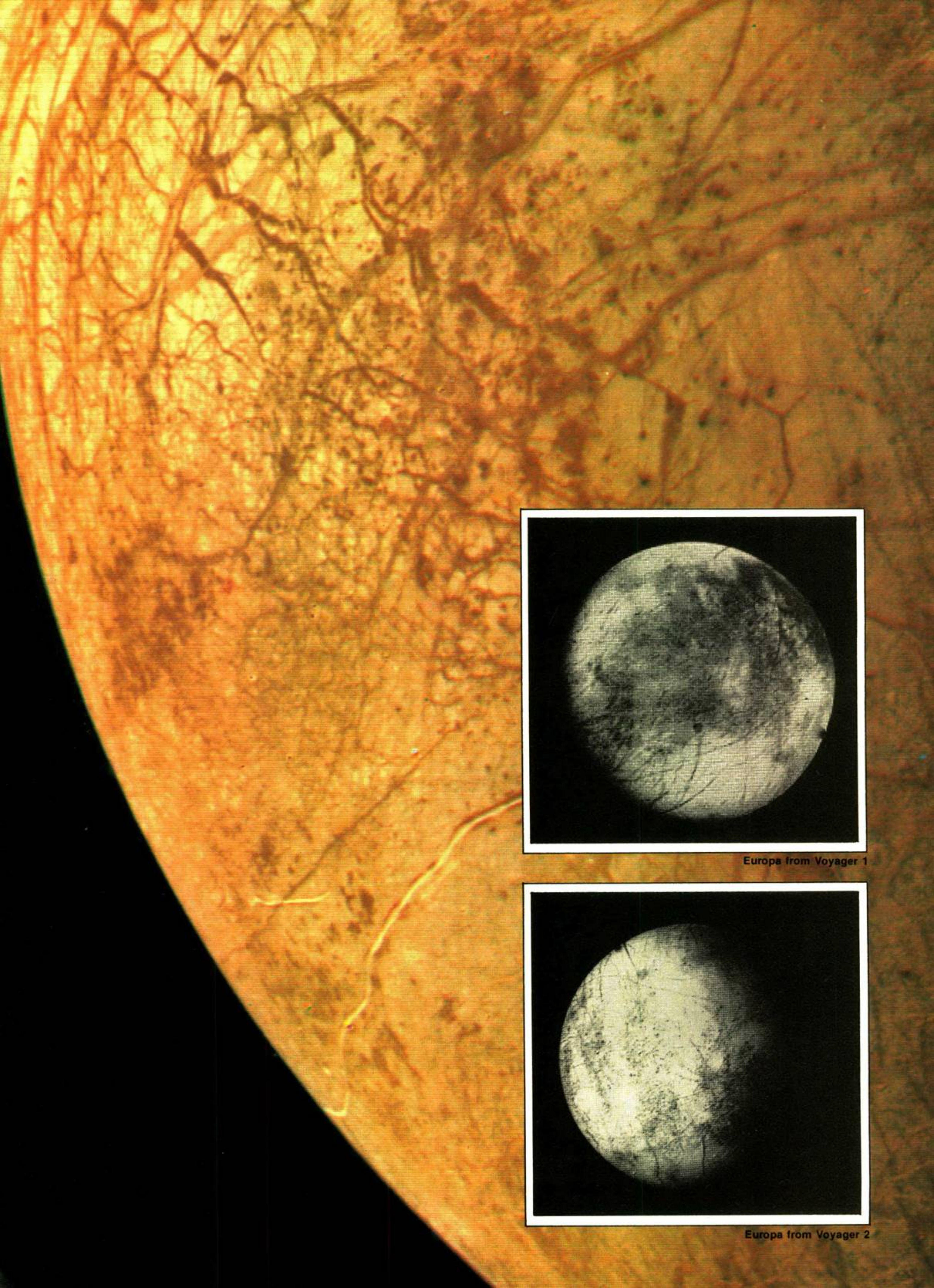


Ganymede has other types of surfaces, too. Some regions are lightly cratered and smooth, with no indication of mountain building. In one place, there is a rough mountainous area that looks more like jumbled lunar mountains than the long ridges and valleys characteristic of other parts of Ganymede. Many of the geologic features seen on Ganymede appear to have been formed by breaking, or faulting, of the crust or by spreading of the crust. In a few cases, there even seem to be indications of sideways motion along faults. This evidence is extremely exciting to geologists, since similar crustal motion on Earth is associated with the drift of continental plates, drawn



Grooved Terrain

Grooved and Dark Terrains



Europa from Voyager 1

Europa from Voyager 2

by convection currents deep in the mantle. Such activity has never been seen before on another planet.

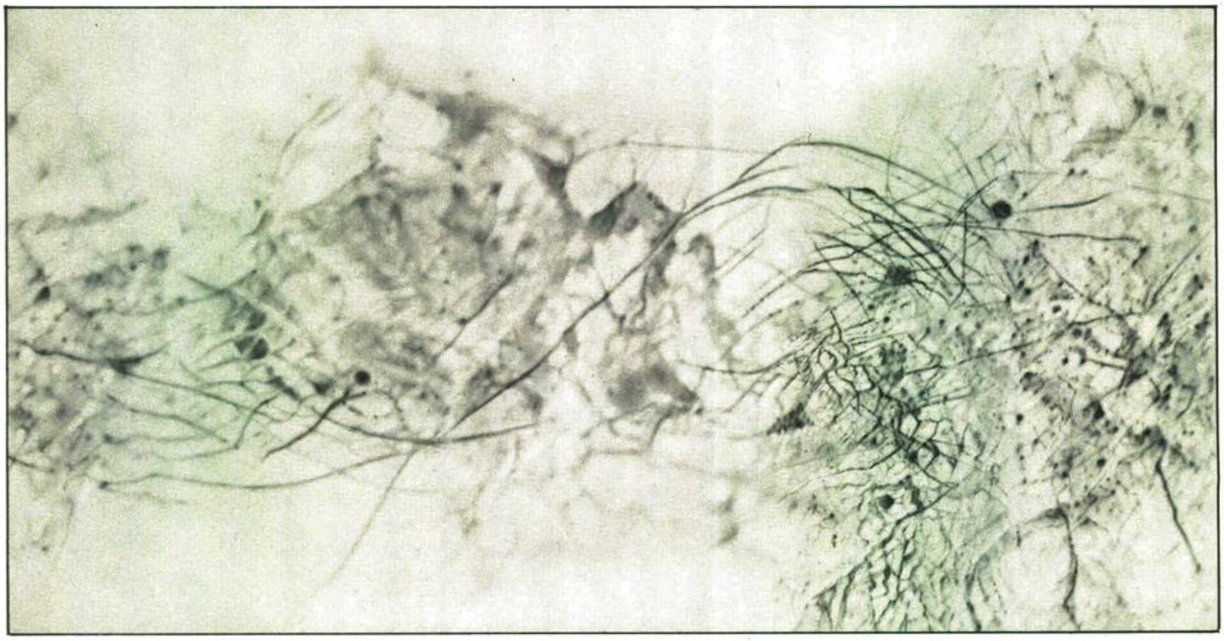
Since 1971, astronomers on Earth had known that about half the surface of Ganymede was covered with exposed water ice, and about half with darker rock. Examination of the albedo variations in the Voyager pictures suggests that the ice is exposed near large craters and, to a lesser extent, in the grooved terrain. Surrounding many larger craters are brilliant white halos and rays. Impacts may have splashed large quantities of subsurface water or ice, rather than dark rocky material, across the surface. However, no direct measurements were made by Voyager of the composition of different parts of the surface.

The presence of ice on the surface further suggested that, before Voyager, Ganymede might have a very tenuous atmosphere of water vapor. Other possibilities were carbon dioxide (a heavy gas) and a tenuous oxygen atmosphere (oxygen can be released by the breakdown of water vapor by sunlight). During the Voyager 1 flyby, the spacecraft was programed to conduct a sensitive test for an atmosphere. The ultraviolet instrument made observations of the star Kappa Centauri as Ganymede occulted it. No dimming of the starlight was seen, placing an upper limit for the surface pressure of the gases oxygen, water vapor, or carbon dioxide of one hundred billionth the atmospheric pressure here on Earth.

The differences between the geologic histories of Ganymede and Callisto are surprisingly large, yet they also show some tantalizing similarities in the dark ringed basins. No one knows the reason why one planet remained unchanged, while the other's crust apparently became active. Perhaps only some small increase in internal temperature is necessary to initiate geological activity in an icy planet, and for some reason Ganymede crossed this threshold for a part of its history, while Callisto did not.

The Rocky Worlds: Europa and Io

As we proceed inward through the Galilean satellites, the worlds become less and less familiar. Callisto and Ganymede were expected to have unusual properties as a result of their large quotient of ice. Europa and Io have densities more typical of the terrestrial planets, so before Voyager flew past them, many scientists expected these two satellites to look much like the Moon — dead cratered balls of rock. They were not: dark streaks crisscrossed Europa's surface, and Io was alive with volcanos.

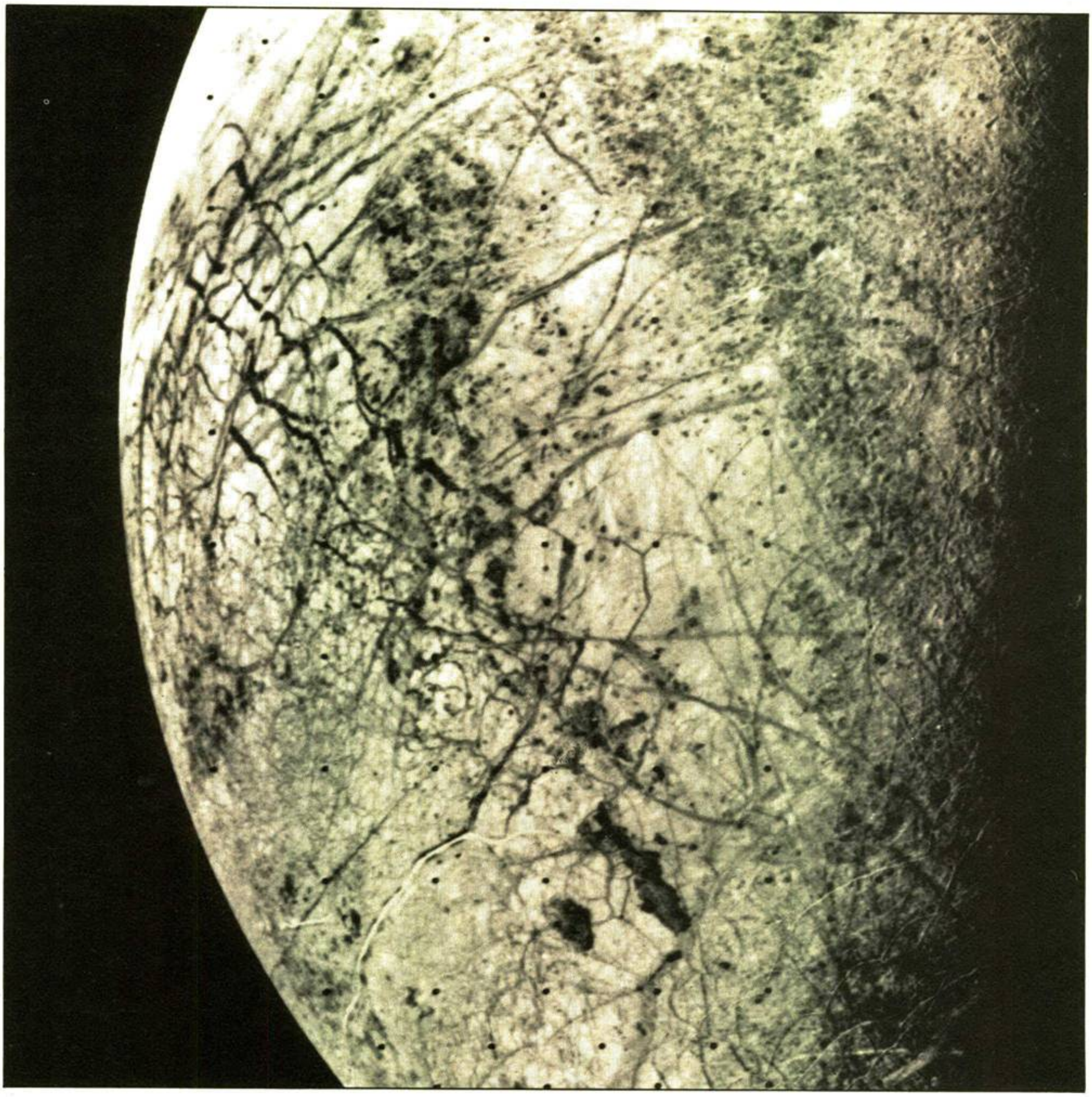


Europa

Telescopic observations of Europa made long before Voyager demonstrated that this satellite is almost completely covered with ice. In the early Voyager pictures, this white, highly reflecting body looks like a giant snowball. As Voyager approached, Europa showed a bland colorless disk — in striking contrast to the spottiness of Ganymede or the brilliant colors of Io. Yet Europa is not a planet of ice — it is rocky.

Europa is about 15% smaller than the Moon. Its density, 3.0 grams per cubic centimeter, indicates that Europa must be basically rocky. However, it is not unreasonable to have some water or ice mixed with the rock, perhaps enough to provide a layer of surface ice many kilometers deep.

Voyager 1 never got closer to Europa than 734,000



Europa's Network of Dark and Light Streaks

km. At that distance, Europa remained nearly featureless. No obvious impact craters, no giant basins, and no familiar geologic structures showed. However, numerous thin, dark lines crisscrossed the surface, some extending up to 3000 km in length. These were something new. Their superficial resemblance to the non-existent canals of Mars caused some joking — but they remained a mystery. As close flyby images from Voyager 2 began to arrive, the scientists were filled with anticipation.

However, the spectacular new pictures were perhaps more confusing than clarifying. Covering most of Europa are streaks that vary in width from several kilometers to approximately 70 km, and range, in length, from several hundred to several thousand kilometers. The streaks are often called "dark," but in fact they are light grey against the white of Europa's surface (the Voyager pictures are contrast-enhanced to show the streaks as dark). While most of them sweep in great smooth arcs across the icy surface, others are strongly curved or irregular. They lie on otherwise smooth, bright featureless terrain — unmarked except for numerous random dark spots, most less than 10 km in diameter.

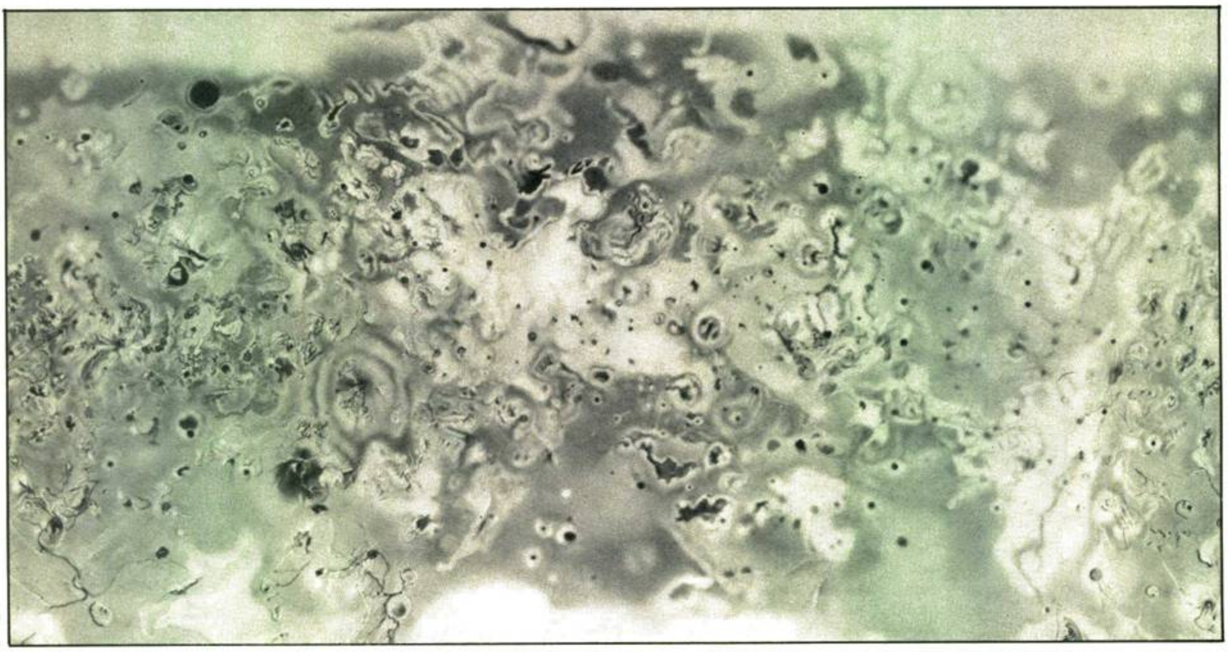
In addition to the smooth terrain (with its streaks), Voyager 2 showed regions of darker, mottled terrain. This mottled terrain appears rougher on a small scale, and possibly it contains small craters just on the limit of resolution (about 4 km). Only three definite impact craters have been identified, each about 20 km across. The small number of craters suggests either that the surface is relatively young or that craters are not preserved for long in the icy crust.

Although its dark streaks give Europa a cracked appearance, the streaks themselves are not cracks. They are not even depressed below their surroundings — in fact they have no detectable relief whatever. They look rather like marks made with a felt-tiped pen on a white billiard ball, though, of course, the ink on the billiard ball is relatively thicker.

Europa also has light-colored streaks. They are only about 10 kilometers in width, and show a vertical relief of — at the very most — a few hundred meters. They are seen best near the terminator and are virtually invisible under high sun illumination. The most amazing thing about the light ridges is their form. Instead of being straight, they form scallops or cusps, with smooth curves that reappear regularly on a scale of one hundred to a few hundred kilometers. In some of the low sun angle pictures, the surface of Europa seems to be nearly covered with a beautiful network of these regular delicately curving lines. Nothing even remotely like them has ever been seen on any other planet.

Today the geology of Europa remains beyond our understanding. Presumably this satellite world has a thick crust of ice, possibly floating on an ocean of liquid water. Presumably, also, there is sufficient heat coming from Europa's interior to have produced cracking or motion in the ice crust, and the pattern of internal activity.

Alternatively, the pattern of cracks — if that is indeed what they are — may have resulted from tidal stresses somehow imparted to Europa long ago. The actual geology — not only interpreting what is seen, but also deciphering how it works — traced on this smooth white world remains another mystery for ever-curious humanity.



The most spectacular of the Galilean satellites is Io. Long before the Voyager spacecraft flew, Io was known for having the reddest color in the solar system. As Voyager approached Jupiter, even the low resolution images made days before the closest approach showed Io's brilliant shades of red, orange, yellow, and white — setting it apart from any other planet. The dramatic scale of its volcanic activity — discovered by the Voyager cameras — confirms that Io is in a class by itself: the most geologically active planet in the solar system.

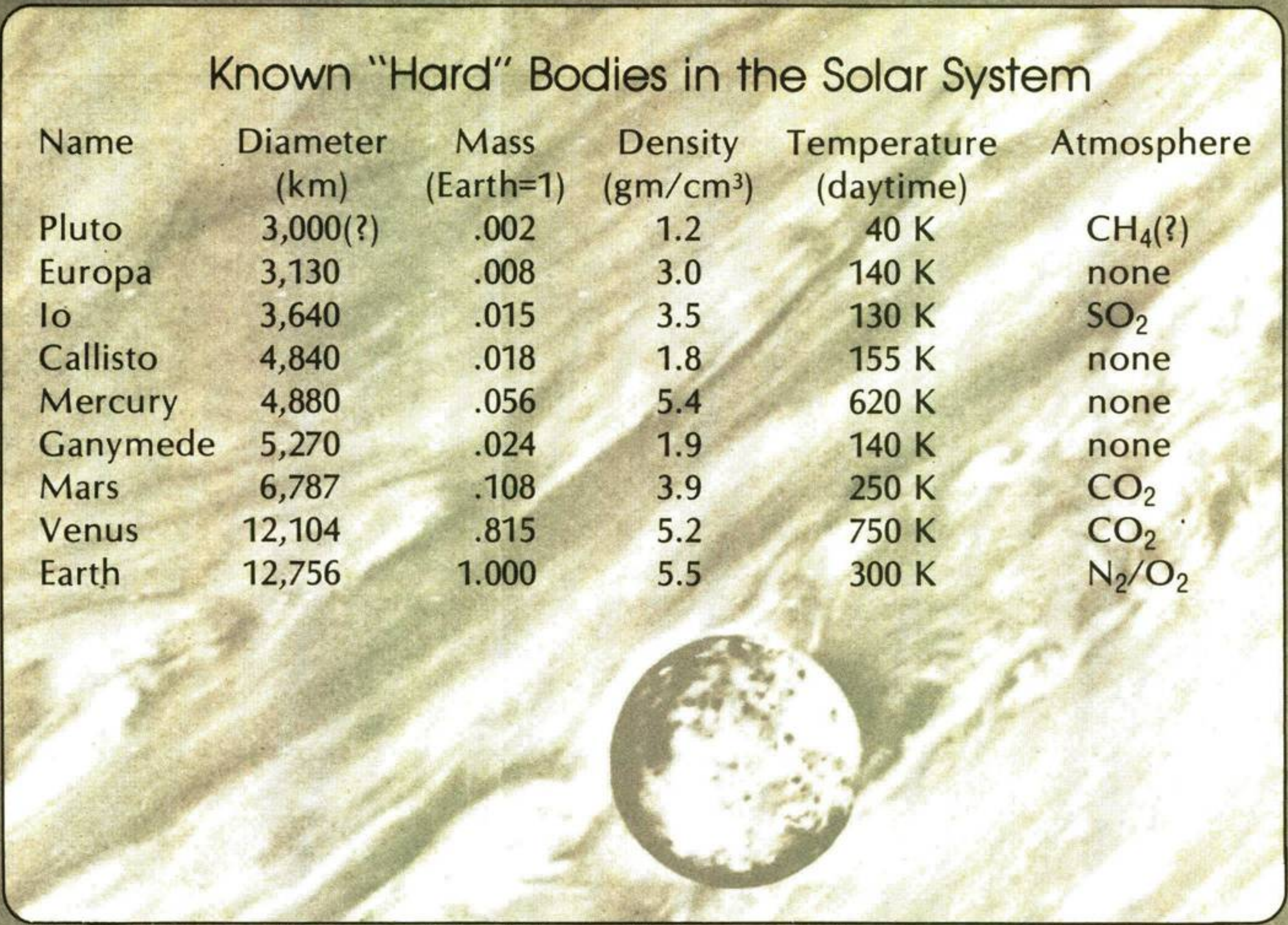
The diameter of Io is 3640 kilometers, and its density is 3.5 grams per cubic centimeter — similar to the values for our Moon. Indeed, were it not for Io's proximity to Jupiter, it would probably be a dead, rocky world much like the Moon.

Io is strikingly craterless. Not one impact crater has been found on Io's surface despite a careful examination of all of the Voyager images. Yet the number of impacts at Io must be greater than it is for the other Galilean satellites due to the focusing effect of Jupiter's gravity. So even if the Voyager images didn't show active volcanos, the absence of craters demonstrates that Io has an extremely young and dynamic planetary surface. Craters certainly form on Io, but they must be filled in — or somehow obliterated — at a rate of at least 100 meters per million years.

In place of impact craters, Io's surface has a great many volcanic centers. Generally these take the form of black spots a few tens of kilometers across. In a few cases, high-resolution pictures show the characteristic shapes associated with volcanic calderas on Earth and Mars. There are not just a few: something like 5% of the entire surface of Io is occupied by calderas. They are extremely dark features, reflecting less than 5% of the sunlight that strikes them. Often they are surrounded by irregular diffuse halos nearly as black as the central spot.

Io's surface also shows extensive surface flows. They originate in the dark volcanic centers and spread to form fan shapes typically a hundred kilometers across, or snake out in long, twisting tentacles. Some of the flows are lighter than the background and some darker. Most are red or orange in color, often outlined by fringes of contrasting brightness.

The discovery of the ongoing eruptions on Io, made shortly after the Voyager 1 flyby, did much to



Known "Hard" Bodies in the Solar System

Name	Diameter (km)	Mass (Earth=1)	Density (gm/cm³)	Temperature (daytime)	Atmosphere
Pluto	3,000(?)	.002	1.2	40 K	CH_4(?)
Europa	3,130	.008	3.0	140 K	none
Io	3,640	.015	3.5	130 K	SO_2
Callisto	4,840	.018	1.8	155 K	none
Mercury	4,880	.056	5.4	620 K	none
Ganymede	5,270	.024	1.9	140 K	none
Mars	6,787	.108	3.9	250 K	CO_2
Venus	12,104	.815	5.2	750 K	CO_2
Earth	12,756	1.000	5.5	300 K	N_2/O_2

clarify the apparent youth of Io's surface. Under the very eyes of Voyager, Io's volcanic eruptions dwarfed anything ever seen before. The discovery picture alone, taken from a distance of four million kilometers, showed two eruptions (Pele and Loki) each larger than the most violent volcanic eruption ever recorded on Earth!

Voyager 1 found eight giant eruptions, with fountains or plumes observed rising to heights of between 70 and 280 km. To reach these altitudes, the material must have been ejected from the vents at speeds of between 300 and 1000 meters per second — several times greater than the highest ejection velocities from terrestrial volcanos. The plumes spread sideways from the vent up to 500 kilometers.

When Voyager 2 arrived four months later, it observed seven of the eight volcanos. Six of them were still erupting. Pele, the largest plume seen by Voyager 1, had ceased activity. The plume associated with Loki had changed markedly, growing from 100 to 210 kilometers in height. Loki also had developed a more complex structure; in March it appeared to originate near the south end of a long dark feature, but in July there was a double plume, with activity at both ends of the dark feature.

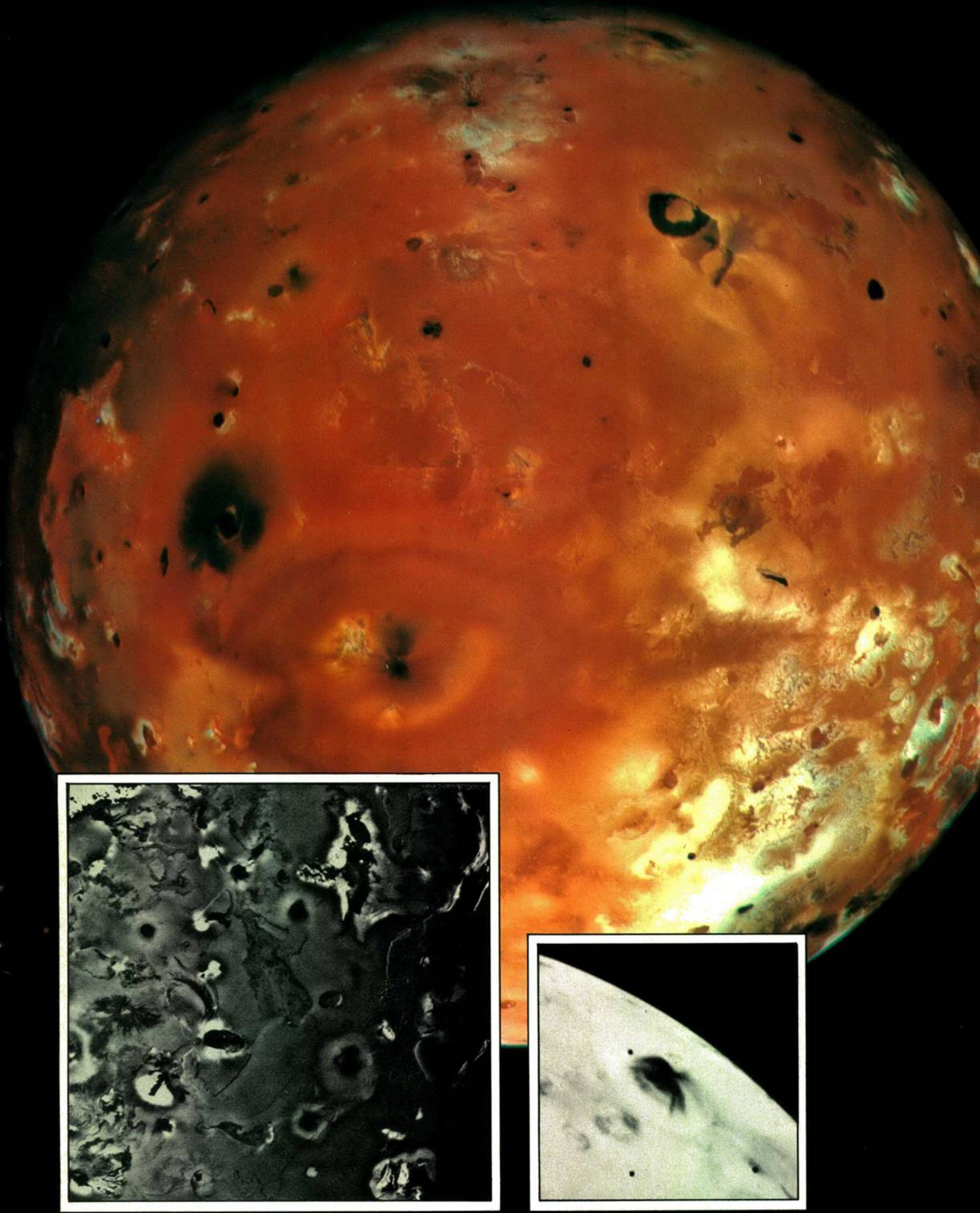
No new eruptions were seen by Voyager 2.

Perhaps the most distinctive surface features on Io are the huge circular or oval dark areas that surround the great volcanos. The first of these to be seen was the 300-km-wide white donut of Prometheus. More spectacular is the "hoof print" around Pele, some 700 by 1000 kilometers. These symmetric rings may be produced by condensible materials — sulfur or sulfur dioxide — raining down from the volcanic fountain. At least one new ring appeared during the four months between the Voyager encounters, but by the time Voyager 2 photographed this area, no plume remained active.

The rings are the visible proof that Io is rapidly resurfacing itself with volcanic material. The plumes, erupting an average of ten thousand tons of material per second — or more than one hundred billion tons per year — will deposit ten meters of material over the whole surface in a million years. When the role of additional surface flows is taken into account, the deposition rate could easily approach a hundred meters per million years, the rate estimated from the absence of impact craters.

The equatorial regions of Io, where the volcanic activity is greatest, are quite flat, with no vertical relief greater than a kilometer in height. Many of the volcanic centers, in fact, don't correspond to mountains or domes at all. There are, however, a number of long, curvilinear cliffs and narrow, straight-walled valleys a few hundred meters deep, apparently places where the crust has broken under tension, somewhat similar to terrestrial faults and the valleys called graben. A few rugged mountains of uncertain origin are visible in low-sun-elevation pictures.

Near the poles, the terrain is more irregular. There are fewer volcanic centers but more



Callisto — 4840 km

Ganymede — 5270 k

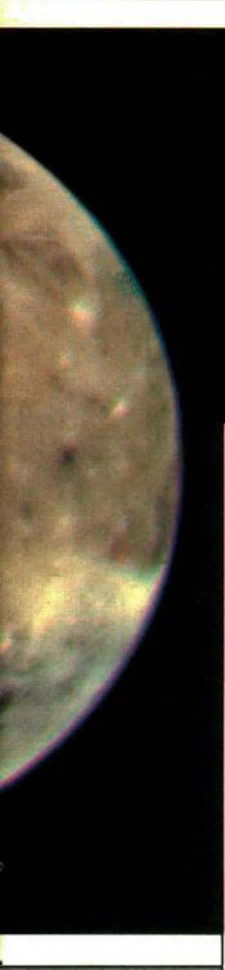
mountains, some with heights of several kilometers. In addition, there are regions that appear to be made of layers of material, called layered terrains. These are revealed where erosion cuts into them, exposing the layers along the cliff. These cliffs may be areas where release of liquid sulfur or sulfur dioxide has undercut cliffs, analogous to internal sapping by groundwater at similar-looking cliffs on Earth.

Io appears to be a study in the geology of sulfur. The brilliant reds and yellows of the surface immediately suggest it: when heated to different temperatures and suddenly cooled, sulfur can assume many colors ranging from black through various shades of red to its normal light-yellow appearance. Even before Voyager, laboratory studies had shown that sulfur matches the overall properties of the spectrum of *Io, i*ncluding the low albedo in the ultraviolet and the high reflectivity throughout the infrared. Contemporary with the Voyager flybys, telescopic observations and laboratory studies established the presence of sulfur dioxide, a compound of sulfur and oxygen. Sulfur dioxide gas is released from terrestrial volcanos, where it combines with water in the Earth's atmosphere to produce sulfuric acid. At the temperature of the surface of Io, sulfur dioxide is a white solid.

Researchers guessed that the extensive bright white areas in the Voyager pictures of Io might be covered with sulfur dioxide frost or snow. Voyager confirmed this when the infrared IRIS instrument obtained a spectrum of sulfur dioxide gas over the erupting volcano Loki during the Voyager 1 encounter.

During the Voyager 1 flyby, temperature scans of the surface of Io were also made with the IRIS instrument. A number of localized warm regions were found, the most dramatic being just south of the volcano Loki. Here the images showed a strange, U-shaped black feature about 200 km across. The IRIS team interpreted their data to indicate a temperature for the black feature of 290° K (17° C, or room temperature), in contrast to the surrounding surface at a frigid 127° K (-146° C). Perhaps the dark feature was some sort of lava lake, either of molten rock or molten sulfur. The melting point of sulfur is 385° K (112° C), but if there were a scum of solidifying sulfur on top of the "lake," this interpretation might well be the correct one.

Clearly, something extraordinary is happening to Io to generate the observed level of volcanism. The



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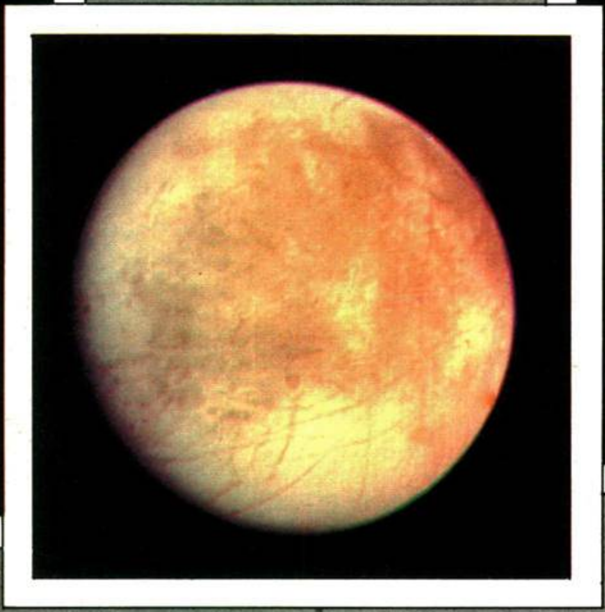
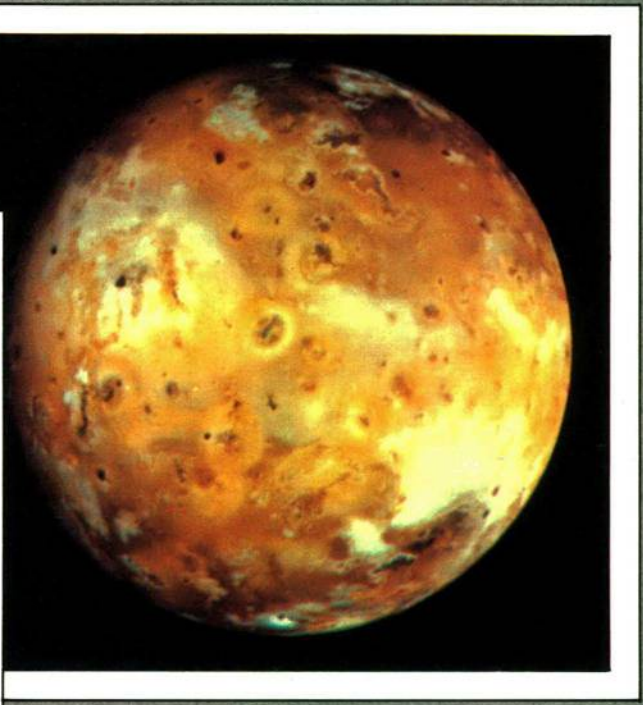
Europa — 3130 km





Io — 3640 km

primary heat source for the interiors of the terrestrial planets is the decay of the long-lived radioactive elements thorium and uranium. But Io would have to have been supplied with a hundred times its quota of these elements to explain the observed activity.

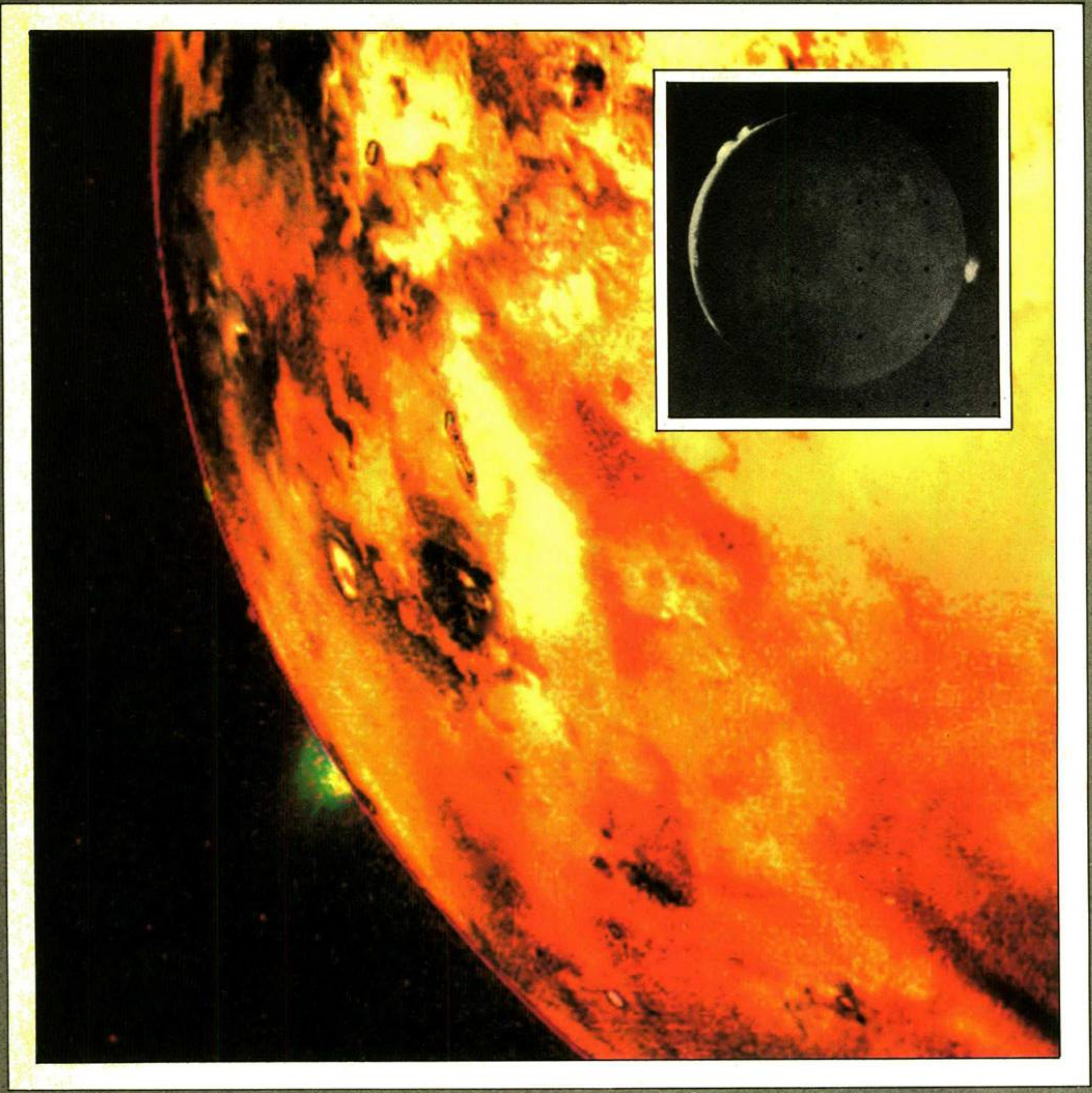
One source that can provide the necessary energy is tidal effects. Io is about the same distance from Jupiter as is the Moon from Earth, but the more than 300 times greater mass of Jupiter raises enormous tides in its satellite, distorting it. No other effect, such as heating, would occur if Io always kept the same distance from Jupiter. But Io's distance from Jupiter varies as the result of small gravitational perturbations from the other Galilean satellites. The tidal distortion also varies, therefore, in effect squeezing and unsqueezing Io each orbit.

Theorists calculated that the heat supplied to the interior of Io could be as much as 10^{13} watts, and predicted, in a paper published just three days before the Voyager flyby of Io, that "widespread and recurrent surface volcanism might [occur]." The Voyager observations appear to confirm these theoretical calculations.

The tidal heat source has presumably been acting since Io was formed more than four billion years ago. With a totally molten interior and continuing large-scale volcanism, Io has had an opportunity to thoroughly sort out its composition. In the process, it lost all of the volatile gases (such as water and carbon dioxide) into space, explaining why Io today has no atmosphere in spite of the continual outpouring of material from the interior. It also explains why Io has sulfur volcanos: most of the sulfur from the bulk interior of the planet could have risen to the surface, where it is recycled again and again through volcanic activity.

In the months since Voyager discovered the volcanos of Io, several efforts have been made to measure the thermal activity with Earth-based telescopes. On at least two occasions, infrared observers have seen remarkable increases in the heat radiation emitted by Io, lasting several hours. Presumably, these events are associated with violent volcanic outbursts, probably larger even than those seen by Voyager. Even between these outbursts, infrared astronomers have detected excess radiation from Io due to numerous hot spots on the surface.

The total heat flow calculated from these observations is about 10^{14} watts, ten times greater than the predicted tidal heat source. No one has yet



Volcanic Plumes on Io

offered a satisfactory explanation for this high level of observed thermal activity.

The large amount of sulfur on the surface may further help explain the extraordinary nature of the Io volcanos observed by Voyager. One model considered for the satellite postulates that Io is covered by a sea of liquid sulfur several kilometers deep, with a crust of solid sulfur and, below the surface, liquid sulfur dioxide. The expansion of the sulfur dioxide explains the very high eruption velocities observed.

The volcanic plumes on Io are apparently made primarily of sulfur and sulfur dioxide. Both are molten as they emerge from the vent, but they quickly cool as the plume rises a hundred or more kilometers into the near vacuum of space. Unlike terrestrial volcanos, there is almost no gas in the plumes. It requires about half an hour for the fine particles of solidified sulfur and sulfur dioxide snow to fall back, where they lie on the surface as the colorful rings that mark the major eruptive sites.

Io is unquestionably a remarkable world. The only planetary body known to be geologically more active than the Earth, it provides many extreme examples to test the theories of geoscientists. And it makes us wonder, when we stop to think about it, at the diversity and beauty we find when we look for it — even in our own solar system.

David Morrison is an astronomer at the University of Hawaii well-known for his interest in the asteroids, planetary surfaces, Saturn's rings, and the Galilean satellites. He is currently a member of the Voyager Imaging Team.

All photographs courtesy of the National Aeronautics and Space Administration and the Jet Propulsion Laboratory.

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Leslie C. Peltier 1900-1980

The following talk was delivered by Les Peltier at the Western Amateur Astronomers Convention in Long Beach, California in 1967.

It is indeed a great pleasure to be here today and to see so many other stargazers spread out here before me in a large cluster.

Now a convention of amateur astronomers is not an easy audience. To address an audience of ordinary people, normal people, it's usually quite a simple affair because knowing nothing or very little of the subject, they accept and apparently relish almost anything that you tell them. At the opposite end of the scale, talking to the genuine dyed-in-the-wool astronomers, they are also a very agreeable lot because from their lofty heights they are prone to look upon even my most exalted and complex celestial cogitations as just a sort of mental coffee break. But for all the in-betweeners, for that vast and growing army of amateur astronomers, what can I possibly say that could be of any interest to them? After all, I've never built a telescope — never even had any inclination to do so. I've never used a setting circle in my life. I've never even seen a UFO.

In my search for a subject, I, in desperation, sought the advice of your own members right here, and they, after racking their several brains, finally came to the conclusion there was only one subject on which I could possibly talk that would by any stretch of the imagination rate me as an authority. That subject was me!

And so today, I am going to talk to you about some of my experiences and some of my impressions of the gentle art of stargazing. Now it's regrettable, of course, that so much of what I have to tell you must be rather autobiographical in nature. But for me in a way that's an advantage because none of you can dispute me, no one can heckle me, no one can question anything that I say because I was there and you were not!

Now stargazing is something that has been very close to me throughout almost my entire life. Let me make it clear, if Tommy Cragg in his introduction hasn't already made it clear, that I am a stargazer and not an astronomer, and that any starlore that may have rubbed off on me during more than half a century of my addiction has come to me from the open sky and not from any classroom or textbook.

Photograph by Robert E. Cox

First of all, I must tell you that I am a sexagenarian (that's merely a person who is between 60 and 70 years of age, in case you're wondering). In other words, I'm an old-timer and so far I'm mighty happy with it. In fact, I've reached that point in life when I like to look back and point with pride to some of the early events, the events of long ago, that I can remember.

I can clearly remember, for example, when the North Pole was discovered back in 1909, and that I gazed in awe at Halley's Comet in 1910. And I clearly remember still that night in April 1912, when the news first reached our town by telegraph that the mighty *Titanic*, on her maiden voyage, was sinking in the North Atlantic Ocean.

Spellbound, I watched such early film epics as "The Birth of a Nation" and "Way Down East," but even before these stars of screen came my way, I was already well introduced to the stars of the sky.

In 1905, when I was just five years old, came my first remembered meeting with the stars: my mother pointed out to me the star group known as the Pleiades through the window of our darkened kitchen on the farm. On an autumn evening two years later, my father showed me the giant planet Jupiter blazing in the sky. Halley's Comet, already mentioned, came along in 1910 and added still more fuel to the flame I imagine was burning at that time.

Our whole family, I recall quite clearly, went out each evening during this apparition and watched it from night to night as it moved among the stars. Now this same Halley's Comet you know is going to be back here in 1986. Now I devoutly hope that those who are specializing in geriatrics will get on the ball, because I certainly would very much like to see this same comet once again.

I'm sure you folks here today are all more or less star-minded. And I know that every one of you, or at least I can safely assume that each of you could at least point out some of the stars to me if we went out at

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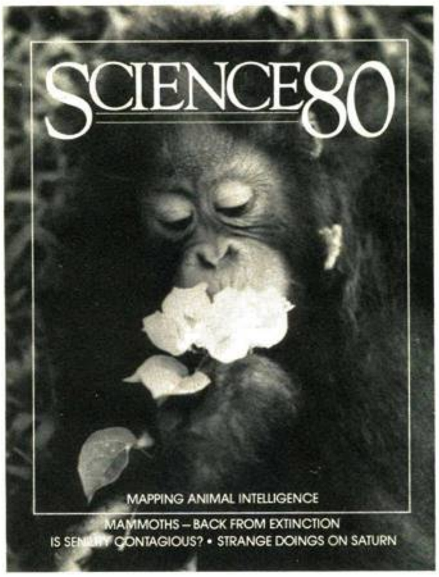
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night. But you're the exception rather than the rule. For after more than 40 years of informally chatting with various people about the stars, I can tell you that the average person does not know a single star in the sky. That's rather odd because most of those same people are fairly familiar with some of the other facets of nature.

They know a few birds, a few trees, some flowers, and all of that, but if they ever got caught out late at night on a lonesome road, they'd have to ask somebody which way was north. Now that is very strange because those stars have been up there every clear night of their lives and they have never bothered to wonder which one is which! One evening just after dark in the spring of my 15th year, I happened to be out-of-doors after dark and for some reason or other, I chanced to look up at the sky and suddenly the thought came to me that with the exception of the Pleiades, the Big Dipper, and the North Star, I didn't know a single one of those hundreds of stars up there.

Now being a farm boy, I was quite familiar with all the birds, the trees, the flowers and the snakes, the lizards and the frogs, and all the other critters that go into the making-up of a farm boy's boyhood, but until that night I had never given one serious thought to the stars up there above me. Well, the next day I borrowed a star book from the library. And that night just after the chores were done, I went through that book page by page until I finally came to a diagram that showed the bright star of Vega just as it would appear coming up in the east in the month of May. Fortunately, it happened to be a clear night that night and it was right in the middle of the month of May. So as soon as it was dark I took that star book in hand, walked outside, went around to the east side of the house, and looked up to the sky and sure enough there was Vega right there before me just exactly as depicted in the book.

You haven't any idea how proud I was of myself. "Must be some special talent of mine," I thought, "to go out there and in just two minutes time find a star."

Among the greatest blessings of those early years, I count the fact that I had no telescope. Now this was not because I didn't want one, for I did, but this was before the days of amateur telescope making, and the few manufactured items on the market were far beyond my means. Today things are vastly different. Telescopes are numerous and fairly inexpensive — and as a rule today the science-minded youngster usually acquires a telescope long before he has any knowledge of the sky. Thus he misses a great many of the early thrills of stargazing: sighting some star that he's never seen before and the learning of its name from some star book or sky map.

Often I am asked by some fond, indulgent parent: "What kind of telescope should I buy for Junior; he's simply crazy about the stars."

I always ask them, "Does little Junior know any of the stars now?" and almost invariably they answer: "No, but he wants to learn."

My ultimatum is, "Then buy Junior a guidebook to the stars and make a good telescope his reward for learning the stars and constellations."

But make no mistake, a telescope is a wonderful thing — and an absolute must for the serious stargazer. When I finally was able to buy one, it was just a little affair, with a lens two inches in diameter and three — no, four — sliding draw pulls that pulled out till the whole thing was three feet long. That little telescope opened up a whole new world to me. I had worked a long, long time to get the $18 necessary for that telescope, and you can be mighty sure that every clear evening thereafter, you could find me right out in the middle of the pasture field looking at the stars.

Here again, fortune favored me. Because until that little spyglass arrived, I had never looked through any other telescope of any size, large or small. And that's really an advantage, because everything that I saw in there was a discovery for me.

Nothing was an anticlimax; nothing was a letdown. It was the biggest thing in my universe, and it was the greatest telescope in the world for me at that time. With that telescope, I could see the mountains and craters on the Moon, the phases of Venus, the rings of Saturn. They were all very clearly revealed. The moons around the planet Jupiter, the planet that I had first seen as a child, were all clearly shown. And in my little telescope the Milky Way became the poet Milton's "broad and ample road, whose dust is Gold/ and pavement [as] Stars...appear."

That little spyglass opened up still another world to me. It showed me that, in at least one field of science, there was still work that the amateur could do that could be of benefit to science. That's unusual today. In spite of the fact that all of our sciences, or major sciences, were originally pioneered by amateurs, amateurs are almost completely crowded out today.

But happily, in astronomy it's quite a different story. I found spread out before me and my little two-inch telescope, more than a lifetime of useful work among the stars.

First, I learned that stars are not as steadfast as they might be. Scattered here and there are stars that vary in brightness. Some of these are bright enough, at times, to be visible to the naked eye. Then just a few weeks later, I would find them far beyond the limits of my little two-inch telescope. A few of these variable stars, as they are called, are at times at least 10 thousand times brighter at maximum than they are at minimum brightness. In charting and recording the magnitudes of these fluctuating stars, there is a crying need for the amateur and his telescope.

I found spread out before me and my little two-inch telescope, more than a lifetime of useful work among the stars.

Now just what is it that makes the amateur observer eager to go out night after night in the clear cold nights of winter to look at the changing brightness of 50 to 100 or more of these fluctuating stars? First of all, I think it's the certain knowledge that you are doing something that is a positive value to science. Secondly, and a little more personal, it is the possibility of doing something that is new, doing some little pioneering of your own, or perhaps seeing something on some particular night that no one else in all the world is seeing or unearthing some quirk or eccentricity in some certain star that no one in all of history has ever noticed before.

For the past couple of years at my observatory, we have been deeply engrossed in following just one of these little unknown pathways. A certain very faint 14th magnitude star was known to be a double star. And it was known too that the plane of this rotation was almost in line with the plane of the Earth, because every so often somebody would notice that the star was much fainter than normal proving that one of those two stars was eclipsing the other one.

Well, it took a good many nights of intermittent spying on that star before we finally caught it in the act of eclipsing. That pair of stars fades, *in just a few minutes* time, from 14th down to 15th magnitude. We watched it on many subsequent nights and eventually caught other eclipses of this star. It never did fail to thrill us to realize that by just watching the amount of light that came from it we could tell that there were two stars revolving about themselves, and that every 4 hours 38 minutes 47 and 8-tenths seconds, one of those stars passed in front of the other one.

At the age of 10, I had no idea that comets were to become so important to me in years to follow. In 1923, Princeton University offered me the loan of a six-inch refractor that they happened to not be using at that particular time. Of course I eagerly accepted. When it arrived, to my great delight, I found that it was the type of telescope known as a comet seeker, meaning it had a very short focal length and showed a large field of sky. Furthermore, this particular telescope had a history: In its early days at the university, it had been used to discover three new comets. So it was only natural that I should try to continue to exercise the special talent of this instrument by also looking for comets.

Somehow or sometime perhaps 10 years after I started looking for comets, I began to grow weary of forever standing at the telescope, climbing the little old stepladder, eternally sweeping that telescope across the sky looking for a tiny bit of misty light that is the first manifestation of an approaching comet. There must be a better way to look for comets.

Eventually I found it. I called it my merry-go-round observatory, for that's precisely what it was. If you can envision a low cubicle building, six feet square, and five feet high with a flat roof, you'd have a general idea of what this merry-go-round observatory looked like. One of the sides has a small door, and on opening this door you can see at once the inspiration for the observatory itself: a swivel chair. If, I thought, I could sit in a chair such as this with a telescope rigidly glued to my eye, it would be easy to search for comets. Well, I just put this swivel chair inside a little building and arranged to rotate the building 360°. I then have a good view of any star above the horizon in solid, cushioned comfort.

Thus far, I have built two complete observatories, rebuilt a third one, and designed a fourth. It is the second of these, my merry-go-round observatory, of which I am the most proud because it still has somes features which I think are unique. Actually this observatory is nothing but an alt-azimuth mounting for the telescope contained inside. All you do is just sit down in that little swivel

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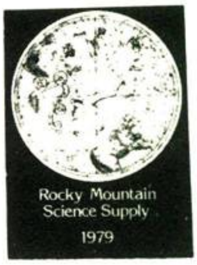

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chair, put your hands on the automobile steering wheel in front of you, and turn around to any part of the sky.

You can be a one-handed driver — and use the other hand to turn the telescope from the horizon clear up to the zenith. The only movement you have to make, besides the movement of your hands, is the tilting of your head. I can easily tilt my head to look through 90° of altitude, allowing, of course, a little eyeball movement in there too.

When the six-inch comet seeker came to me from Princeton, it was quite elaborate. It had a mahogany tube, brassbound, and it was on a heavy iron equatorial fitted with circles. It even had a very impressive weight-driven clock drive.

One by one these luxuries were discarded. I realize this is completely contrary to all the rules and regulations of modern telescopes. You don't subtract things — you add them. Have you looked at some of the modern telescopes? They have so many gadgets and attachments that you can't find the telescope anymore!

It seems that man, the more civilized and refined he becomes, the more cultured he is, the more he's afraid of the dark. In my own case, I've found that the skies, the once-dark skies, have been getting brighter and brighter. It's brought my cometseeking almost to a halt.

But it seems that each time we come to a dead end of one avenue, another opens up. About seven or eight years ago I got a telephone call at night, a long distance call from Miami University, and they offered me the gift of their entire observatory: the building, the 22-foot dome, twelve-inch Clark refractor, a chronograph, astronomical clock, transit instrument — all that I would have to do would be to remove it from their campus to my home.

Now the performance of any telescope is determined largely by its light-gathering power. The twelve-inch that I had just been offered collected fully four times as much light as my old six-inch and 36 times as much as my little two-inch spyglass. Furthermore since the name of Alvan Clark engraved on any telescope doesn't depreciate its value too much, you have no idea how quickly I accepted that offer of theirs.

I had a choice of two locations for the new observatory. I could either take it out to the old farm where I used to live or put it right on the city property close to the house. I finally decided on the latter, because I knew that the telescope would be used much more if it were close at hand. And so it was finally placed on somewhat of a low hill about a city block north of our house — within 50 feet of the merry-go-round observatory.

The various celestial objects scattered about the skies that I have observed so often in my smaller telescope are truly a revelation when seen through the great power of the twelve-inch. Celestial showpieces such as the Orion Nebula, M-13 in Hercules, the Ring Nebula in Lyra, the Edge-On Nebula in Coma Berenices, are all completely charming and much more realistic than you'll ever see them in any photograph. The Moon itself — now while I've never been a confirmed moon watcher, the amazing detail that I could see on the surface of the Moon has created a very, very real threat of me going into something like that. My only regret in connection with this telescope is that it didn't come along 40 years sooner.

Painting by William Close

Like my old telescopes, I'm somewhat a product of the 19th Century, and somehow I have never made it over into the 20th Century. Part of this I think is because of my vast preference for the tranquil times of that era, and part because, astronomically at least, I have never grown up.

Who has ever supplanted such men as Barnard, Brooks, Burnham, Heinrich Olbers, Lewis Swift, William Denning? Not that there are not astronomers gifted with the facility for yard-long theorems or equations today. But these were not men to indulge in long-haired theories: each one of them was an observer with a keen eye and a telescope eager for every starlit night.

And being brought up, almost weaned, on the works of Jules Verne and H. G. Wells, I have always strongly favored the exploration of the solar system. It is man's desire to know what is going on around him that makes him more than just another animal. And as one who, for the past 50 years, has watched the Moon and the planets from afar, I have a more than ordinary curiosity in seeing what they are really like close-up. But I would gladly curb that curiosity for a little while until we get old Mother Earth cleaned up a little first. Our suddenly scientific Uncle Sam is gambling 25 billion dollars in an effort to land a man on the Moon and bring him back alive again — at a time in our history when we can't even land a man in Havana, Cuba and get him back safely.

What has this tirade, my weak protest against the times being out of joint, to do with looking at the stars? Only this: it's times like these that make me mighty glad to be a stargazer. For I can leave this problem planet almost any time I want to. I have only to go out to my observatory, close the door behind me, open up the dome, swing the telescope into position, and I'm off to the serenity of the world of stars.

In his nocturnal wanderings about the skies, it is the stargazer who, of all the children of the Earth, is the one least touched by all this frenzied turmoil of the times. In his communion with the stars, he is in nightly touch with both the eternal and the infinite. And the measures of his tranquil world, the miles from star to star, and the years from age to age, are far from the angry bickerings of this petty world we live in.

Were I to write out one prescription designed to help alleviate at least some of the self-made miseries of mankind, it would read like this: "One gentle dose of starlight to be taken each clear night just before retiring."

Thank you.

Over the years, Les has been an inspiration to all of us amateur astronomers, with his 50 years of monthly reports of variable stars to the AAVSO. A man with 12 comets and 4 novae to his name, he contributed a grand total of 130,000 variable star estimates, made mostly from starfield charts and comparison star magnitudes he had memorized — a real contribution to our knowledge of the stars. After the dedication of Ford Observatory on East Table Mountain in the Angeles National Forest, we named that mountain after him: Mount Peltier.

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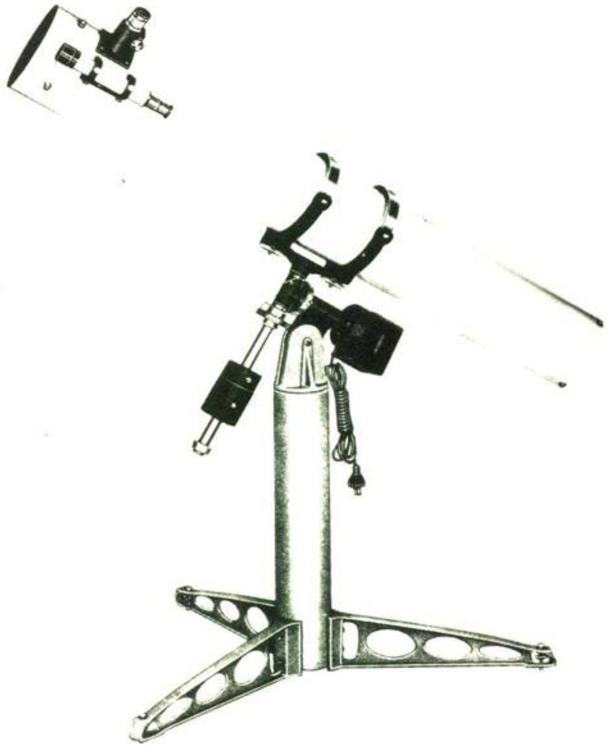

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eye
on the
sky

a small harvest of planets

the wanderers

The planetary sky-pickings have become decidedly thinner as summer fades into fall. Jupiter and Saturn have disappeared behind the Sun and Mercury won't appear either; only Mars and Venus can be found easily.

When the sky darkens after sunset, **Mars** is the yellowish-orange dot of light very low in the southwest. At the beginning of September, it sets 2 hours after the Sun; by month's end this will drop back to 1¾ hours.

Shining at magnitude +1.5, Mars is now about 2 times farther away from us than we are from the Sun. Even a telescope wouldn't improve your view much.

Currently at the eastern edge of the constellation Virgo, during September Mars will move eastward along the ecliptic more than halfway into Libra. By the time the Sun catches it next April, it'll have run all the way around to Pisces!

Once Mars sets around 9:00 p.m. local daylight time, you won't see any naked-eye planets until Venus comes up 4 hours before the Sun. The second week of September is when **Venus** will reach its maximum height in the east and at magnitude -3.8, it'll outshine all the other planets put together.

Venus' background constellation is Cancer and on the mornings of the 14th and 15th it will lie just to the south of a prominent star cluster there: M-44, also known as the Beehive. To the naked eye, the Beehive is a faint unresolved glow which immediately breaks up into stars with any optical aid (like binoculars). If you have a pair, take them out and get an "improved" view of Venus and the cluster.

Jupiter and **Saturn** both lie on the other side of the Sun from us. The Sun passes Jupiter on the 13th and just 10 days later, does the same to Saturn. As a result, both planets stay hidden in the bright light of the Sun for essentially the entire month. Jupiter will be appearing in the morning sky, very low in the east just before sunrise, at the end of September; Saturn won't reappear until mid-October.

Where's **Mercury**? Officially, it's in the evening sky and has been since August 26th, but because its position on the celestial sphere lies very far to the south, we just won't get a good look at it during this apparition. Greatest elongation comes on October 10th, but you'd have to be pretty lucky to spy it even then. Wait until November rolls around, when Mercury'll put on an excellent morning appearance.

Many people know that the full moon in September (full phase comes during mid-morning on the 24th) is known as the **Harvest Moon**. This is when the Moon, full or nearly so, rises only a little later each night, its rays lighting up the landscape after the Sun has set.

To watch this wonderful phenomenon yourself, go outside and look east at sunset starting around the 22nd of the month. There'll be the Moon, big and round, rising about 30 minutes later each night. (At the time of the spring equinox in March, the daily delay in rising runs about an hour.)

Earth gets a mention this month too because on the 22nd at 5:09 p.m. EDT, fall begins in the northern hemisphere: this is the autumnal equinox. The Sun is crossing the celestial equator into the southern celestial hemisphere; day and night are equally long with the Sun rising and setting due east and west. It'll remain in the southern hemisphere until March 20th, 1981.

the starry sky

September may be the month when summer changes to fall, but as you go outside at the end of twilight on a clear evening and look up, it's plain the summer stars are with us yet.

High overhead lies a conspicuous trio. Straight up is **Vega**, the brightest star in **Lyra** (the lyre). A little to the northeast you'll see **Deneb**, the luminary of **Cygnus** (the swan), while below and between Vega and Deneb lies **Altair**, of **Aquila** (the eagle). These three stars form an asterism (or informal grouping) called the **Summer Triangle**.

Bisecting the sky like a cleaver, the silvery sweep of the **Milky Way** passes nearly north-south through the Summer Triangle. Buried in it to the south lie two prominent constellations, **Scorpius** (the scorpion) and **Sagittarius** (the archer). Sagittarius looks like a gigantic teapot, tipped to pour boiling water onto the tail of the scorpion below. (There's even steam coming from the pot's snout — the Milky Way!)

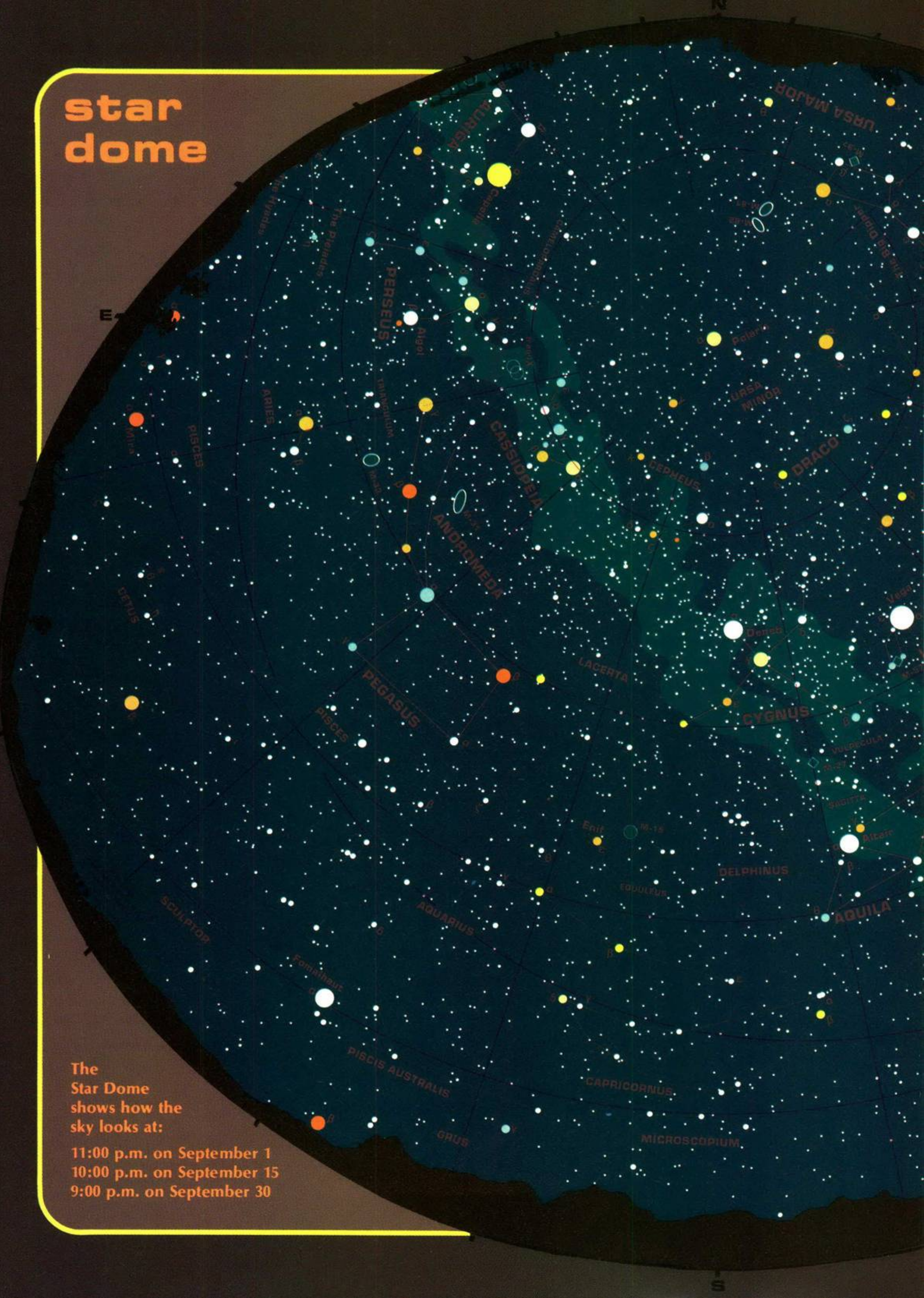
Scorpius' brightest star is ruddy **Antares** — so-called because of its resemblance in color and brightness to Mars (Ares in Greek). Late next month around sunset, sharp-eyed observers will get a chance to compare the two directly as Mars, then very low in the western sky, will pass just north of Antares.

The Milky Way clumps especially thickly between Antares and Sagittarius and for very good reason. This is the direction in which the center of our **Galaxy** lies, hidden from sight by thousands of light-years of dust and glowing gas. Yet the center can't hide completely, for the thickened bulge and clouds of stars betray its presence, nevertheless.

Yet what of fall? Why is it that all the summer stars are still around? Two

Top: Steve Reed was camped on Palomar Mountain when he took this shot showing the Moon and Mercury (the dot at middle right). He used a 200 mm lens and 64 ASA film. Below: Dave Rabenhorst shot the Big Dipper with his camera's normal lens and 400 ASA slide film. The exposure ran 12 seconds.

star dome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Enif
M-15
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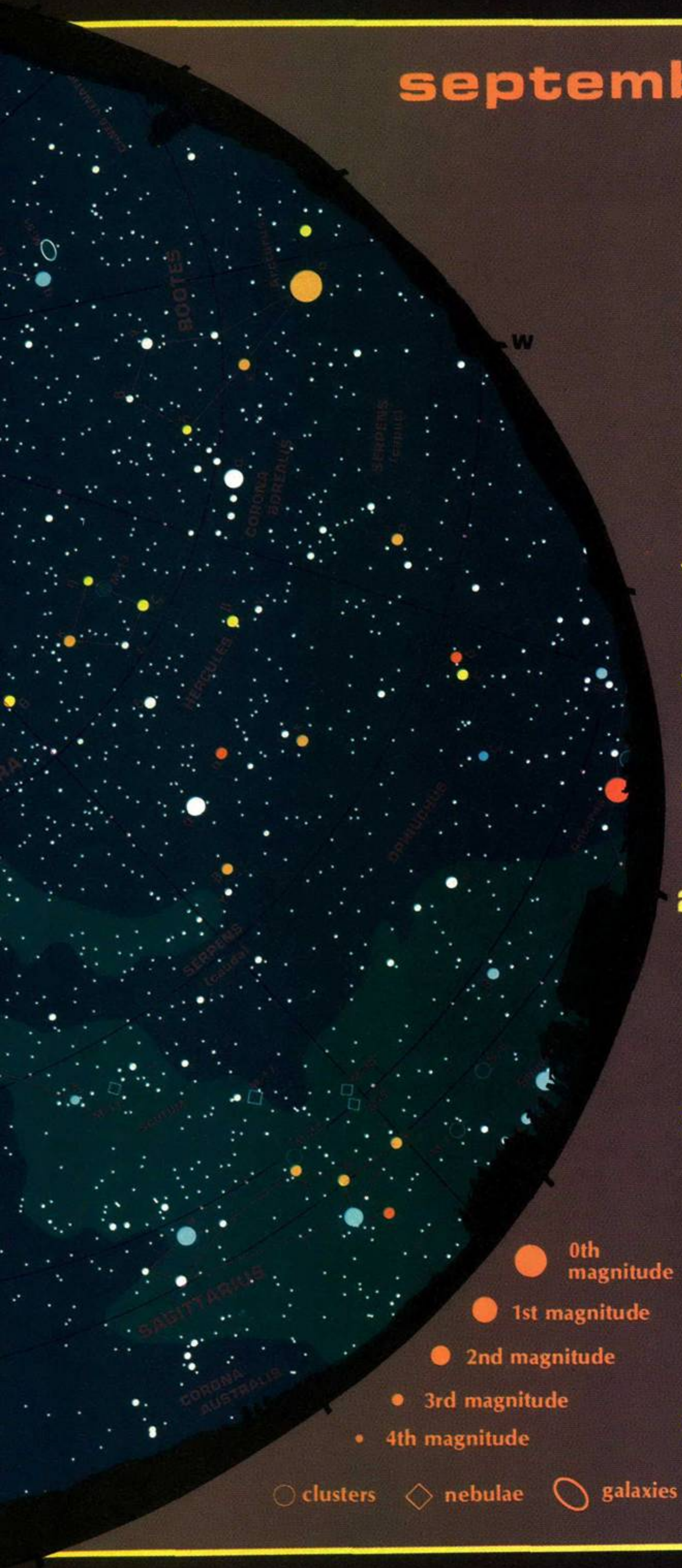
AQUARIUS
SCULPTOR
Fomalhaut
PISCIS AUSTRALIS
CAPRICORNUS
GRUS
MICROSCOPIUM

The Star Dome shows how the sky looks at:

11:00 p.m. on September 1
10:00 p.m. on September 15
9:00 p.m. on September 30

september sky almanac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SERPENS (cauda)
SAGITTARIUS
CORONA AUSTRALIS
0th magnitude
1st magnitude
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

1st The Moon is at last quarter phase at 2:08 p.m. EDT today.

9th New moon comes at 6:00 a.m. EDT. Weather permitting, the nights around new moon afford the best opportunities to get out of the light-polluted city and see some really dark skies.

12th Moon is at apogee (farthest distance from Earth) this morning: 251,867 miles.

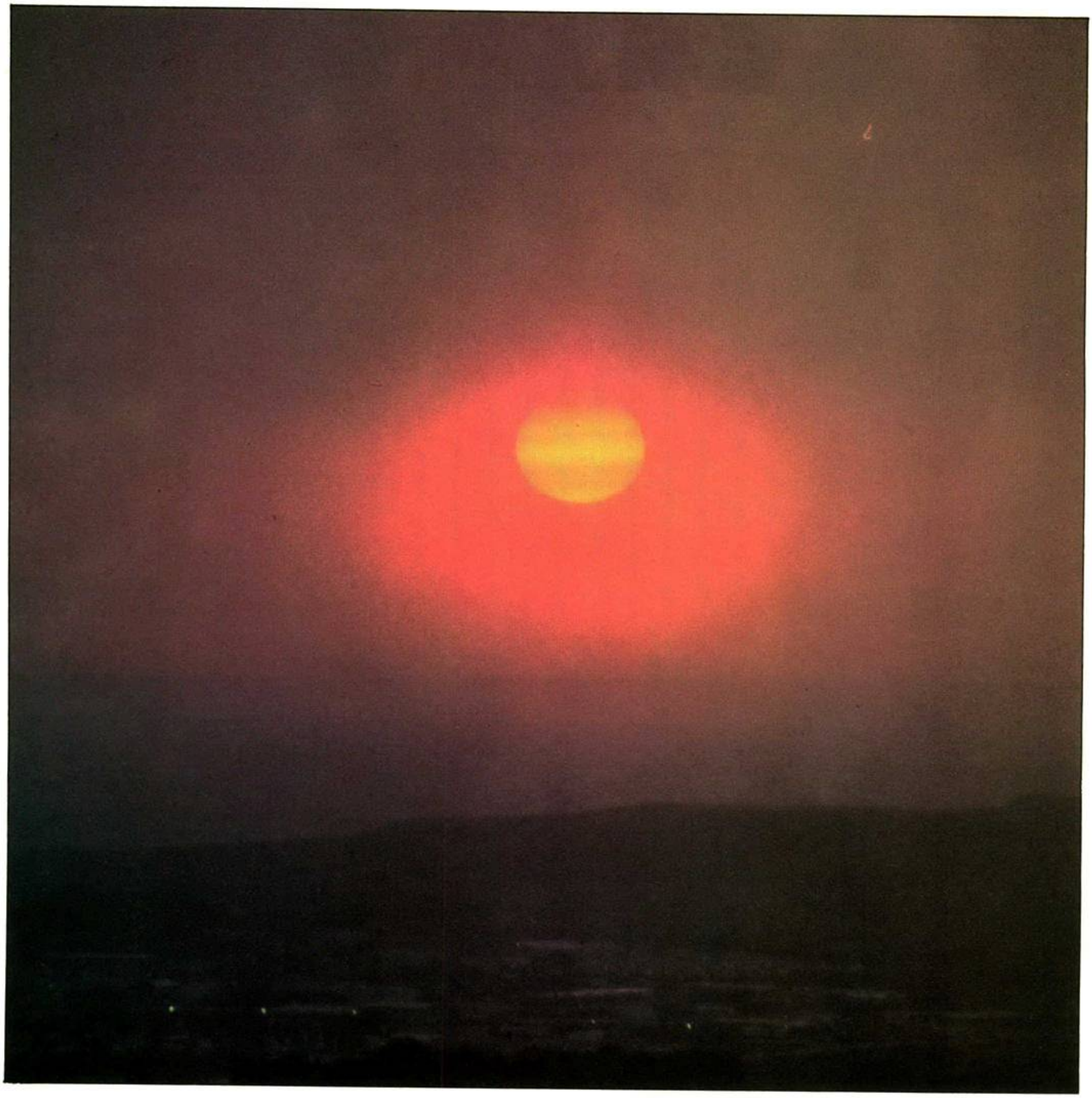
13th Jupiter lies directly opposite Earth on the other side of the Sun today.

17th First quarter moon (a good time for cratergazing) happens at 9:54 a.m. EDT.

22nd The equinox is at 5:09 p.m. EDT today; autumn begins in the northern hemisphere. Saturn lies directly opposite Earth on the other side of the Sun today.

24th Full moon (the Harvest Moon) is at 8:08 a.m. EDT. Tonight and for a couple of nights to come, the Moon will rise only a little later each night. Also: the Moon is at perigee (closest to Earth) late in the evening: 221,612 miles.

30th Last quarter comes again today at 11:18 p.m. EDT.



Jeff Belet of Rapid City, South Dakota was impressed by the optical effects of volcanic ash from the Mount St. Helens eruptions. He took this sunrise shot May 28th with a 300 mm lens and 200 ASA slide film. (The Sun's apparent flattening came about due to refraction in the Earth's atmosphere, not the eruptions.)

unrelated effects are conspiring to keep the summer groups visible out of season; one is apparent, the other real.

The first reason is nothing more than the brilliance of the star groups themselves. Fall constellations simply lack the brilliance of the summer ones that naturally attract your attention.

The other reason is that the end of twilight comes earlier and earlier each night (almost an hour earlier between one end of September and the other). Couple this earlier time of sunset with the natural cycling of the constellations and they seem to progress only half as fast.

In fact, if you were to go outside at the same time (by the clock, not when the Sun sets) each clear night, you'd see the usual parade of stellar groupings as it changes.

With all that squared away, the thing to do now is go out a little later tonight and get acquainted with those autumnal groups. (For this reason, the Star Dome map is set for the late evening hours.)

The largest and most easily recognized of fall constellations is **Pegasus** (the flying horse), a minor but crucial figure in this month's skylore section. As the map shows, it'll be about halfway up the sky in the east, resembling nothing so much as a giant diamond. Of the four stars marking the diamond, one actually belongs to **Andromeda**, the neighboring constellation to the northeast — that's why the map shows two Alphas (α).

The two brightest stars are named **Alpheratz** (the left "facet" of the diamond) and **Scheat** (the top one). Together with **Markab** (on the right) and **Algenib** (at bottom), the diamond shape — usually known as the **Great Square** because of how it looks when Pegasus lies on the southern meridian — forms the flying horse's body. Or at least that's how many people see it today.

Some newcomers to stargazing get frustrated when star patterns don't resemble their mythological names very closely, but this misses the point. While a literal representation would certainly be an arresting sight, a loose correspondance spurs on your imagination — and maybe provides more fun in the end.

Between the Great Square and the Milky Way lies a dim region with few landmarks. One of the most curious is **Delphinus** (the dolphin), a small collection of 4 stars in a rhomboid shape with a 2 or 3-star hooked tail extending to the south.

A wonderful folk-name for the constellation is "Job's Coffin." Its two brightest stars are called **Sualocin** and **Rotanev** — names listed in an 1814 star catalog that commemorate in Latin, when spelled backwards, Niccolo Cacciatore, an assistant at the Palermo Observatory, where the catalog was issued!

You won't find Delphinus easily from the city — a short trip out of town for dark skies may be necessary — but once you've located its distinctive shape, you'll never miss it again.

To the left of Delphinus and a little below lies another faint constellation, **Equuleus** (the little horse). An ancient group dating back to the Greeks, Equuleus has only a few stars to mark its presence.

Continuing to the lower left, you meet the zodiacal constellation of **Aquarius** (the water-carrier). Spread out roughly east-west, Aquarius' shape looks like a pair of bent wire-rim spectacles. Its brightest stars (none too bright at that) lie in the center, between the two spectacle lenses (water jugs, in mythology). They are called **Sadalsuud** and **Sadalmelek**.

West (right) of Aquarius lies another zodiacal constellation, **Capricornus** (the sea-goat). Triangle-shaped, Capricornus extends east-west, with its two main stars, **Giedi** (topmost) and **Dabih** (just below), at the triangle's western apex.

skylore

It is only within the lifetime of many still living that man has gained the power of flight through the air, a power long dreamed of through centuries of earth-bound plodding. And a power indeed it is, especially in warfare, where mastery of the air is now recognized as an essential element of victory. The Battle of Britain in 1940, when German and British air forces fought each other far above the ground, was a battle unprecedented in military history.

Yet the potential military advantages of manned flight have long been obvious. The ancient Greek myth of Pegasus and Bellerophon illustrated these advantages in terms of those for whom the horse was one of the most powerful "war machines."

Pegasus, the winged horse, was the offspring of Poseidon (god of the sea) and the Gorgon Medusa, whom Perseus slew. It must be said that Medusa, famed for being so ugly that the mere sight of her face was enough to turn you to stone, was originally beautiful, and it was in that state that she caught the eye of Poseidon. But he foolishly arranged an intimate tete-a-tete with her in one of Athena's temples, so angering the goddess that she transformed the lovely Gorgon into a fearful winged monster with a horrible mouth and glaring eyes. And talk about problem hair! Athena also insured that Medusa could never again have a nice coiffure by replacing her hair with a mass of writhing, hissing snakes guaranteed to daunt even the most talented (to say nothing of courageous) hair stylists. Who wants to deal with hair that bites your fingers and eats your combs?

Perseus, of course, managed somewhat to alleviate Medusa's ugliness by the rather extreme expedient of removing her head entirely, a practice frowned upon in the better beauty salons. Pegasus then sprang from her dead body and flew away to visit the Muses, create wells, and engage in other rather unhorselike activities.

Meanwhile Bellerophon, through no fault of his own, had gotten into rather a mess. An exile from Corinth, he angered the wife of the King of Tiryns by rejecting her amorous advances and she retaliated by telling her husband that he had tried to seduce her. Unwilling to kill a guest, the King sent Bellerophon to Iobates, his wife's father and the King of Lycia, with a letter that read in effect: "Please terminate with extreme prejudice the bearer of this letter, for he has tried to rape your daughter, my wife."

Iobates was equally unwilling to kill a guest, so instead he gave Bellerophon an assignment that he felt sure would prove to be his undoing: to slay the Chimaera, a fire-breathing menagerie-in-one with the head of a lion, the body of a goat, and the tail of a serpent.

Realizing he needed some help in this task, Bellerophon, with the help of Athena, managed to tame Pegasus and thereafter rode him high above the Earth on his many "missions impossible." After disposing of the Chimaera, Bellerophon was given other military assignments by Iobates, who obviously decided he had a good thing going here. Bellerophon even engaged in some primitive bombing missions, dispatching opposing warriors by dropping big boulders on their heads as he flew above them on Pegasus, just out of bowshot.

Finally, when Bellerophon and Pegasus had eliminated all of the King's enemies, Iobates sent out the palace guards to ambush him on his return. Forsaking for the time the assistance of Pegasus, Bellerophon called on Poseidon for help. The god of the sea sent a great tidal wave rushing across the Xanthian plains before Iobates' palace. The wall of water advanced as far as Bellerophon and no farther, but Bellerophon insisted on marching right on up to the palace.

Iobates was saved by what must be one of the weirdest scenes in all of Greek myth: The Charge of the Xanthian Women. It seems that all the women of the tribe who had their homes on the Plain of Xanthus gathered together, hauled their skirts up over their waists, and ran wildly toward Bellerophon screaming for him to take them, one and all, instead of destroying their homes.

Bellerophon, understandably enough, was appalled by the sight of a stampeding herd of wild, screaming women holding up their dresses and rushing toward him. Feeling quite unequal to the task, he turned tail and scurried away as quickly as possible, the tidal wave conveniently retreating with him.

Witnessing this, Iobates decided that either Bellerophon was a man of considerable modesty and honor or his sexual tastes just didn't run much to the feminine gender. Either way, he figured that Bellerophon couldn't have been guilty of the charge of seduction, so he showed him the letter and asked for an explanation. Satisfied by his account of what really happened in Tiryns, Iobates forgave Bellerophon, allowed him to marry another of his daughters, and made him his heir.

Bellerophon, though his troubles had ended, refused to settle down peacefully to a life of comfort and luxury. In a fit of vainglory he mounted Pegasus once more and presumed to fly up to Olympus, where he could be immortal. But Zeus, angered by Bellerophon's audacious ambition, sent a gadfly to sting Pegasus. The great winged horse reared in pain, unseating Bellerophon and casting him down to Earth in a humiliating heap.

Zeus rewarded Pegasus, however, by allowing him to complete the flight to Olympus, where he carries the thunderbolts of Zeus as the god's own personal war-horse. Pegasus now has his place among the constellations, and ever since, the heliacal rising of Pegasus (just before the Sun) marks the beginning of the season of spring and summer thunderstorms. The air-power of Pegasus thus belongs, appropriately enough, to the god of the air himself.

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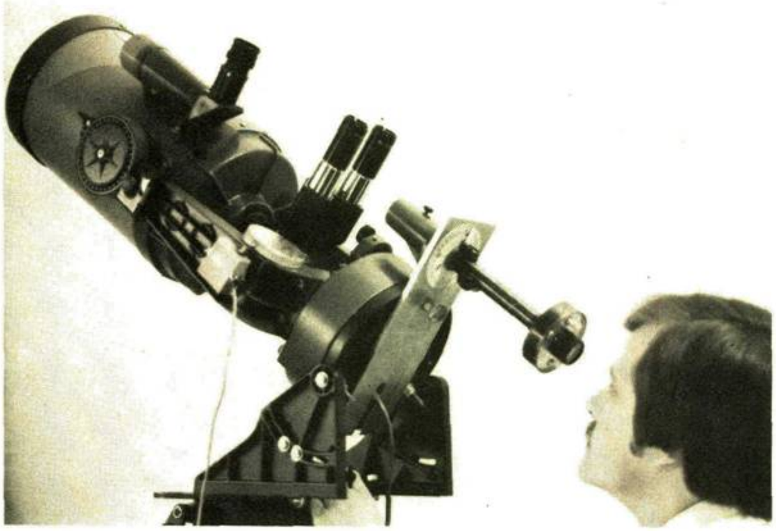

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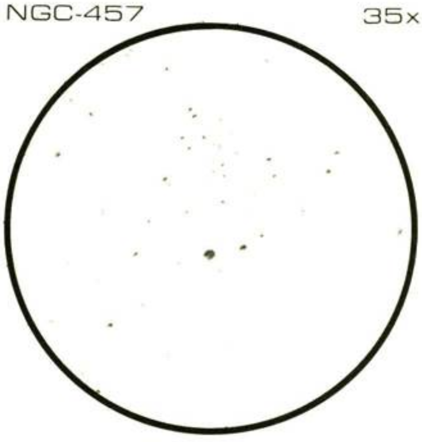
21 challenging deep-sky objects

by
Dave Eicher

Deep-sky observing has been growing rapidly over the past several decades with the arrival of larger, better-built, and more commonly available telescopes. An "average" homebuilt or commercially-purchased telescope (which these days runs in the 8 to 12-inch class) can reveal several thousand objects.

Obviously, deep-sky objects (any object lying outside of our own solar system) comprise the overwhelming majority of possible "targets" on which to spend your observing time. It matters not what type or size of telescope you own, although some are better suited for deep-sky observing than others. Whether you have a small refractor, large reflector, or medium-size catadioptric, there will be objects available for inspection at any given time, and many will look terrific.



Although the objects we're presenting here are billed as "challenging," some will be more so than others, depending on your observing skills, telescope type, and seeing conditions. In Gazer's Gazette for October 1979, we introduced the "top 21" deep-sky objects — the brightest and best, naturally.

Here we're extending that listing of showpieces with 21 objects of lesser renown. Equally as intriguing and often presenting more beautiful and mystifying sights than the common deep-sky objects — especially in medium to large instruments — these targets can still be reached with smaller telescopes. Given good nights of seeing and some practice, you'll be pulling these in with the smallest pieces of glass.

Whatever your observing setup, experience, or interests, probing past the showpieces into a world of dim spirals, close pairs, wispy nebulae, and dimly glowing clusters is a truly rewarding experience. You'll surely be able to show your friends a few "new ones" at the next local star party.

The objects are listed in order of right ascension, and are scattered enough to ensure that several are above the horizon at any given time. Obviously seeing conditions, observing technique, magnification, telescope type, and experience will dictate the degree of success you may achieve in observing some of these objects. But remember to take your time, choose a clear, dark night, and above all, enjoy yourself!

NGC-404

NGC-404 is a challenging 12th magnitude elliptical galaxy in the same low-power field of view as the bright star Beta (β) Andromedae. Although its size and magnitude make it troublesome for smaller scopes, a little patch of faint, fuzzy nebulosity can be seen in 6 to 8-inch instruments with good seeing.

The fact that NGC-404 lies near such a bright star does not remove all difficulties in spotting the galaxy. Try placing the star just outside of the field, while centering the galaxy as much as possible. Once you have located it, slightly higher magnifications may aid in observing this faint gathering of suns.

NGC-457

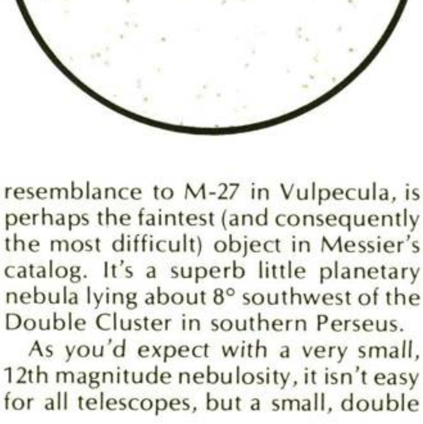
This small cluster is a favorite of mine and an unforgettable sight in any telescope. Lying just two degrees from the third magnitude star Delta (δ) Cassiopeiae, it's amazing that the 7.5 magnitude grouping (containing 100 stars brighter than 13th magnitude) was not cataloged by Messier.

NGC-457 is especially appealing in a low-power field, and its shape resembles an owl — to me, anyway — by virtue of two bright stars marking its eyes and several lines of stars forming its body and wings; I therefore dub it the "Owl Cluster."

The 5th magnitude star Phi (ϕ) Cassiopeiae on the edge of the group is not a true cluster member; however, note the very red, somewhat dimmer star near Phi which is a member.

M-76

M-76, also called the "Little Dumbbell Nebula" because of its resemblance to M-27 in Vulpecula, is perhaps the faintest (and consequently the most difficult) object in Messier's catalog. It's a superb little planetary nebula lying about 8° southwest of the Double Cluster in southern Perseus.

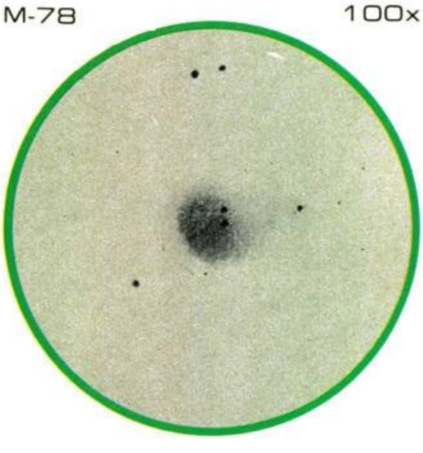


As you'd expect with a very small, 12th magnitude nebulosity, it isn't easy for all telescopes, but a small, double patch of dimly glowing gas can be seen with medium to large scopes and proper magnification. Something to keep in mind when observing M-76 is that it seems to take magnification fairly well — don't be afraid to use shorter focal length eyepieces or Barlow lenses when applicable. If you experiment with several different setups for this planetary, you're sure to be delighted with the results.

Gamma (γ) Andromedae

Certainly one of the very finest double stars for small telescopes, Gamma is a striking yellow-greenish blue pair. The 5th magnitude greenish-blue companion lies about 10 arc-seconds away from the 2nd magnitude primary. It's a beautiful sight in all telescopes, especially at medium powers.

M-78 100x



Quite an interesting situation exists here — the companion itself is a close double (with a 6th magnitude companion about 1 arc-second distant), and the brighter member of this pair is also a spectroscopic binary, making Gamma a quadruple system.

M-78

M-78 is a very unique telescopic sight and probably one of the finest examples of a reflection nebula — where the light from a bright star is reflected from the nebulosity.

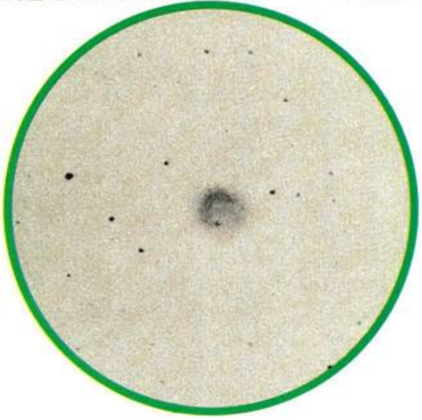
This relatively small nebula appears as a rather round, uniform glow involving several stars, one or two of which may be illuminating the gas and dust. Often overlooked because of its close proximity to the Orion Nebula, M-78 is truly a worthwhile object for any scope, and really becomes interesting in larger aperture instruments.

M-35 & NGC-2158

One of the finest low-power or binocular views in the northern sky is the open cluster M-35 and its elusive mate NGC-2158 (an open cluster, also). M-35 is a very large, bright, scattered cluster that's worth attention from even casual deep-sky observers, and the fact that the region provides a bonus in the form of NGC-2158 is simply icing on the cake.

An extremely low-power view is best suited for observing the shape of M-35, and binoculars are eminently suitable. If high powers are used, you'll simply get lost in the dense background of stars. A large richest field telescope (RFT) will provide a breathtaking view of this region on dark nights.

NGC-6781 100x

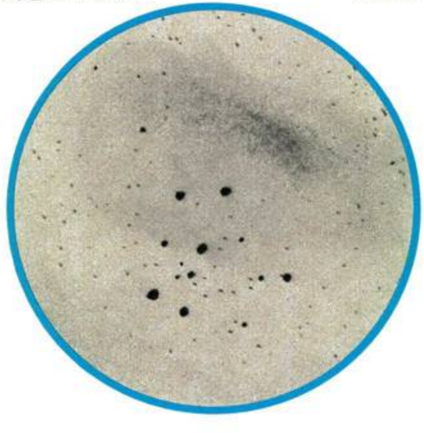


NGC-2158, on the other hand, is much smaller, much more dense, and will take high power quite well. With an integrated apparent magnitude of 11, the small cluster contains about 40 stars, most of which are about magnitude 16. To locate it, use a low-power ocular on a dark night, slowly sweeping the southwest side of M-35. Given a good night and the proper setup, this region will become one of your favorites.

The Rosette Nebula

The Rosette Nebula is very "controversial" because of its dimness — the associated emission nebulosity (NGC 2237-9) is extremely difficult to glimpse, even under the best conditions and with large telescopes. However, small scopes and binoculars show the open cluster (NGC-2244) very well and it is a splendid sight at low power.

NGC-2237 35x



The 5th magnitude gathering contains about 46 stars, some of which are fairly bright. Several types of instruments may show some nebulosity in the region; large binoculars or RFTs at low power would be ideal, using a slow and steady sweeping motion. For telescopes with long focal lengths, a visual telecompressor would be quite useful.

Sirius

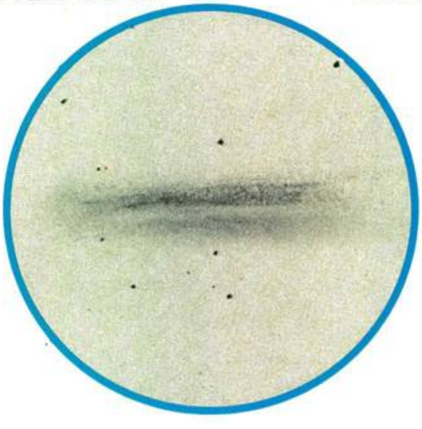
At magnitude -1.42, Sirius is the brightest of all stars. Interestingly, it is also a close double star of notable interest to amateur observers. Sirius itself shines brilliant white and the companion, Sirius B, is a magnitude 8.5 star lying just 10 arc-seconds distant. It orbits Sirius once every 50 years. At maximum separation (11.5") in 1975, it has now begun to close up.

With the blinding glare from Sirius, you'll find it extremely difficult to spot the companion, even on the best of nights, with small and medium-size scopes. The star has been spotted routinely in telescopes of 12 to 24-inch aperture, and under the best of conditions even in 6 to 8-inch instruments.

Castor

Unlike Sirius, Castor has two components that are nearly equal in brightness. Castor A, at magnitude 2, and Castor B (lying 4 arc-minutes distant to the northeast) at magnitude 2.8, are both visible in medium-size scopes at high power. A third component, Castor C, lies 71 arc-minutes distant to the south-southeast and shines at 9th magnitude. Each star is also a spectroscopic binary, making Castor a system with six suns.

NGC-3628 100x



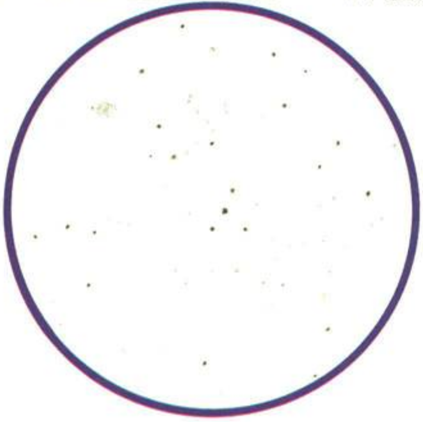
M-46 & NGC-2438

The large open cluster M-46 and its region present a unique sight — an excellent Messier open cluster with a planetary nebula projected upon its face. The nebula, in fact, is much closer to us than the cluster.

A low-power, wide-field ocular is best suited for observing the cluster — a spectacular sight, containing some 220 stars and retaining an apparent magnitude of 6.6. Lying within the rich group, about 7 arc-minutes from its northern edge, is the 11th magnitude nebula, resembling a dimmer version of M-57 in Lyra.

The ring shape is easy to pick out in medium-size scopes, and very impressive at high powers. The ring's 16th magnitude central star is, of course, exceedingly difficult.

M-46 & NGC-2438 170x



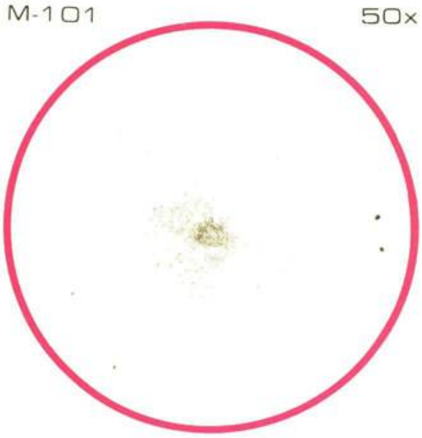
NGC-3628

Lying in the same low-power field as M-65 and M-66, NGC-3628 is an 11th magnitude galaxy in Leo possessing a prominent dark lane, visible in small scopes and outstanding at medium powers. Lying so close to M-65 & M-66, and measuring some 12 arc-minutes in length, this is another object which somehow, surprisingly, avoided being awarded a Messier number. When observing NGC-3628, take note of the dark lane structure and whether or not any other detail is visible.

M-101

After reading in a typical reference book that M-101's magnitude is 9 and then observing an extremely faint haze in its listed position, you might easily be disappointed by this galaxy. However, if you understand that it is spread-out and therefore use an extremely low-power field with medium to large aperture, you can observe much of this galaxy.

M-101 50x



Since the massive spiral arms and involved nebulosity spread over an area of 25 minutes of arc in diameter, field sweeping is essential. With medium aperture, a general spiral haze with knotty arms and bright and dark patches can be seen on very good nights. A faint haze or nebulous patch can be seen even in binoculars, so M-101 is a galaxy that offers something for everyone.

NGC-5897

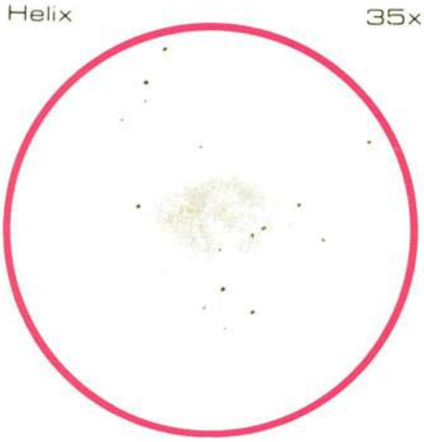
NGC-5897 in Libra is a very loose, dim globular cluster which is a challenging object for virtually any telescope. At magnitude 9, the dimness of the individual stars and sparseness of the group make the cluster hard to spot, even in binoculars or RFTs.

At low power in medium-size scopes, the group appears as a faint, circular glowing haze with little or no central condensation. The diameter of the cluster is about 8 minutes of arc, making it an interesting and unusual sight in telescopes able to pick up the glow.

Antares

Alpha (α) Scorpii, or Antares, is our last double star. Its conspicuous red color is matched by a small, dim, greenish secondary 3 arc-seconds away, which shines at magnitude 6.5. It is by no means easy for small or even mid-size scopes to separate, but given good seeing, high powers, and at least some aperture, the pair can be split.

Helix 35x

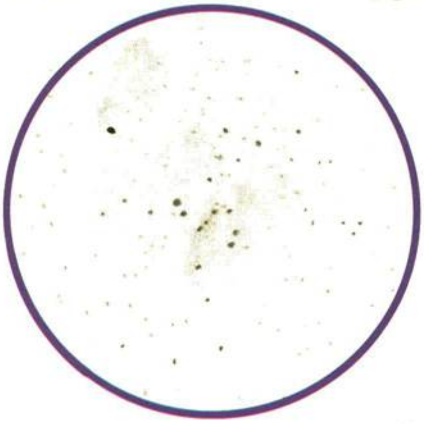


The Eagle Nebula

The Eagle Nebula (M-16) is one of the most complex objects in the sky. It's made up of a widely scattered open cluster easily observable in small scopes and binoculars, and a large emission-nebula region with a sprinkling of dark nebulous patches projected upon its face.

Different observing setups can produce quite different views of this object. In small scopes, binoculars, or finderscopes, the region appears as a fairly bright, large patch of mixed nebulous light and stars. In larger telescopes, some of the nebulosity seems to resolve into stars, while some faint nebulosity remains. The dark globules can be seen in medium-size instruments on very good nights, and almost routinely in larger ones. A low-power eyepiece is usually sufficient for spotting most of its detail.

M-16 50x



M-22

M-22 is certainly one of the finest globular clusters in the sky — upstaged only by 47 Tucanae, Omega (ω) Centauri, and perhaps M-13. At magnitude 6.5, and measuring 17 minutes of arc in diameter, M-22 is an easy binocular object and resolves well even with small telescopes. The cluster's easy resolvability makes it a good test for seeing conditions, and it would be interesting to note what magnification resolves the cluster completely, and how small a scope can accomplish the feat.

It's easy to find, lying 2° northwest of Lambda (λ) Sagittarii, and best observed with medium powers in small and medium-size scopes. In large telescopes, with good seeing, the cluster presents an amazing sight at high magnification.

M-56

M-56 is a small but fairly bright globular, worthwhile for any telescope. It's often ignored due to the close proximity of well-observed M-57. M-56 lies almost midway between Gamma (γ) Lyrae and Albireo (Beta [β] Cygni), and is easy to find in wide-field oculars. The globular takes medium and high magnifications, but does not resolve well. At 5 arc-minutes in diameter, it's fairly large and at magnitude 10, is accessible in most finderscopes.

NGC-6781

This planetary may not be bright, but it is a fantastic sight in good-size telescopes, resembling a dimmer, more circular, more evenly-illuminated M-57. Although listed at magnitude 12.5, I usually have no trouble picking it up in an 8-inch f/5 telescope. The

21 challenging deep-sky objects

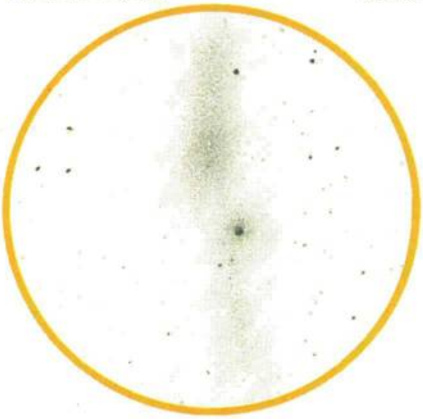
name	common name	r.a.	dec.	type	constellation
NGC-404		01ʰ 06.6ᵐ	+35°27′	gal	And
NGC-457	Owl Cluster	01 15.9	+58°04′	open cl	Cas
M-76	Little Dumbell Nebula	01 38.8	+51°19′	pl neb	Per
Gamma (γ) And	Almach	02 00.8	+42°06′	dbl st	And
M-78		05 44.2	+00°02′	refl neb	Ori
M-35 & NGC-2158		06 05.7	+24°20′	open cl	Gem
NGC-2237-9, 2244	Rosette Nebula	06 29.7	+04°54′	open cl+em neb	Mon
Alpha (α) CMa	Sirius	06 43.0	−16°39′	dbl st	CMar
Alpha (α) Gem	Castor	07 31.4	+32°00′	dbl st	Gem
M-46 & NGC-2438		07 39.6	−14°42′	open cl+pl neb	Pup
NGC-3628		11 17.7	+13°53′	gal	Leo
M-101		14 01.4	+54°35′	gal	UMa
NGC-5897		15 14.5	−20°50′	glb cl	Lib
Alpha (α) Sco	Antares	16 26.4	−26°19′	dbl st	Sco
M-16	Eagle Nebula	18 16.0	−13°48′	open cl+em neb	Ser
M-22		18 33.3	−23°58′	glb cl	Sgr
M-56		19 14.6	+30°05′	glb cl	Lyr
NGC-6781		19 16.0	+06°26′	pl neb	Aql
NGC-6960, 6992-5	Veil Nebula	20 43.6	+30°32′	snr	Cyg
NGC-7293	Helix Nebula	22 27.0	−21°06′	pl neb	Aqr
NGC-7331		22 34.8	+34°10′	gal	Peg

extent of the nebulosity is about 105 arc-seconds, making it best seen with medium powers, but unless the seeing is quite good, very high ones are probably detrimental.

The Veil Nebula

The Veil Nebula (NGC-6960, 6992-5) is another one of those large, scattered nebulosities that draws a lot of controversy. A supernova remnant, its brightest parts are without question visible under good conditions in large RFTs — or even binoculars under dark skies.

NGC-6960 35x



Although it seems to have no formal magnitude assigned, the brighter parts are around magnitude 12.5 or 13. NGC-6960 (the western part) is much easier to find, because it streams through the star 52 Cygni for a distance of about 70 arc-minutes. NGC-6992-5, actually somewhat brighter than 6960, lies roughly parallel about 2° northeast.

If low-power, wide-field observing is called for anywhere, it's with the Veil Nebula. Use an extremely wide-field ocular with slow, steady sweeping. If conditions aren't absolutely perfect, or you're not using enough aperture, the nebulosity may appear only as a change in the background skylight — very subtle.

Be careful to distinguish what you actually see from what you have seen in many photographs! Much of the Veil is visible, given exceptional nights and the proper setup. I've seen a tremendous amount of the nebulosity on superb nights using an 8-inch telescope at f/5 and a 28 mm wide-field ocular.

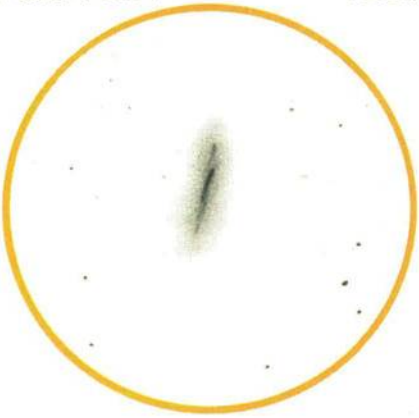
The Helix Nebula

NGC-7293, the Helix Nebula, is yet another controversial nebulosity that keeps deep-sky observers happily disputing. Again, with an extremely good night, a southern horizon free of light pollution, and a medium to large-aperture scope with a wide-field eyepiece, the Helix (which measures 15 x 12 minutes of arc) appears as a circular, faint, nebulous patch. Don't let the 6.5 magnitude estimate fool you — it's spread out so much that it becomes a really difficult object. But in large aperture instruments, the Helix is a fantastic sight.

NGC-7331

Our last object is a fine, bright galaxy accessible to all instruments. Measuring 10 x 2½ minutes of arc and shining at 10th magnitude, the galaxy can be located easiest with a low-power ocular. Having found it, switch to a higher power for spotting details within the nebulous mass. There are several heavy dark lanes bordering on its western rim, and a number of bright nebulous patches within the spiral arms, both of which are satisfyingly difficult.

NGC-7331 100x



Dave Eicher is a physics student at Miami University. He's also the editor of **Deep-Sky Monthly**, *an observing periodical with a superbly self-descriptive title. (Subscriptions are $9 a year from: 104 Oakhill Dr., Oxford OH 45056.)*

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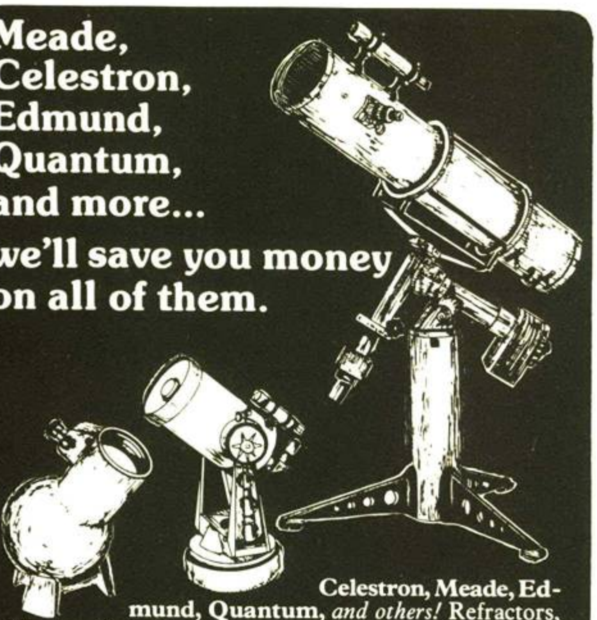

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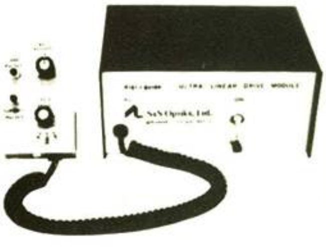

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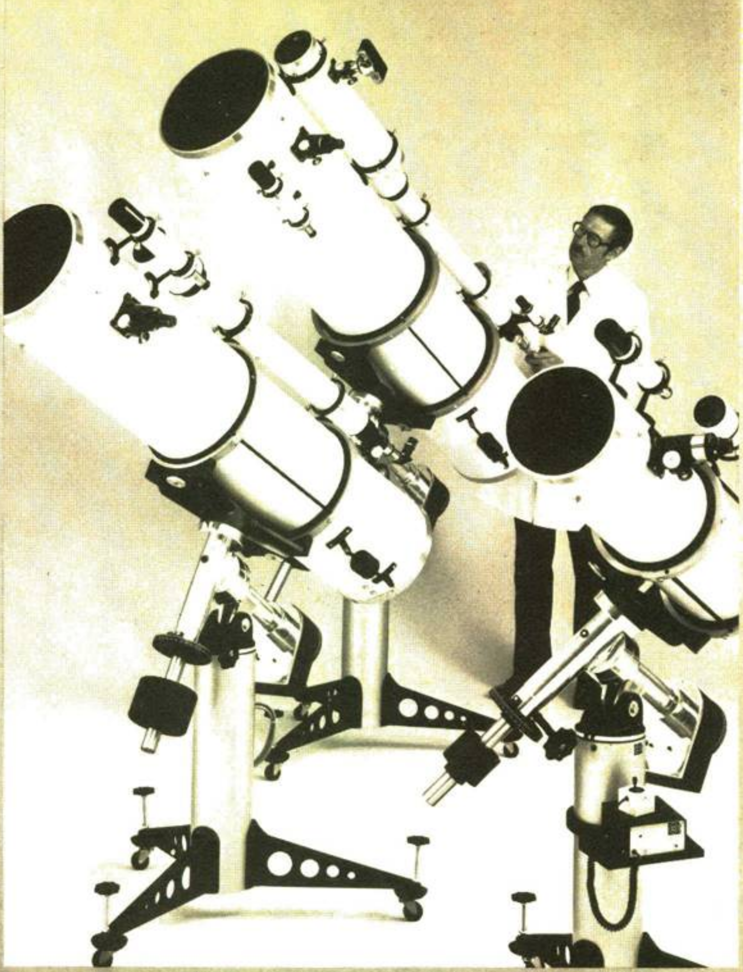

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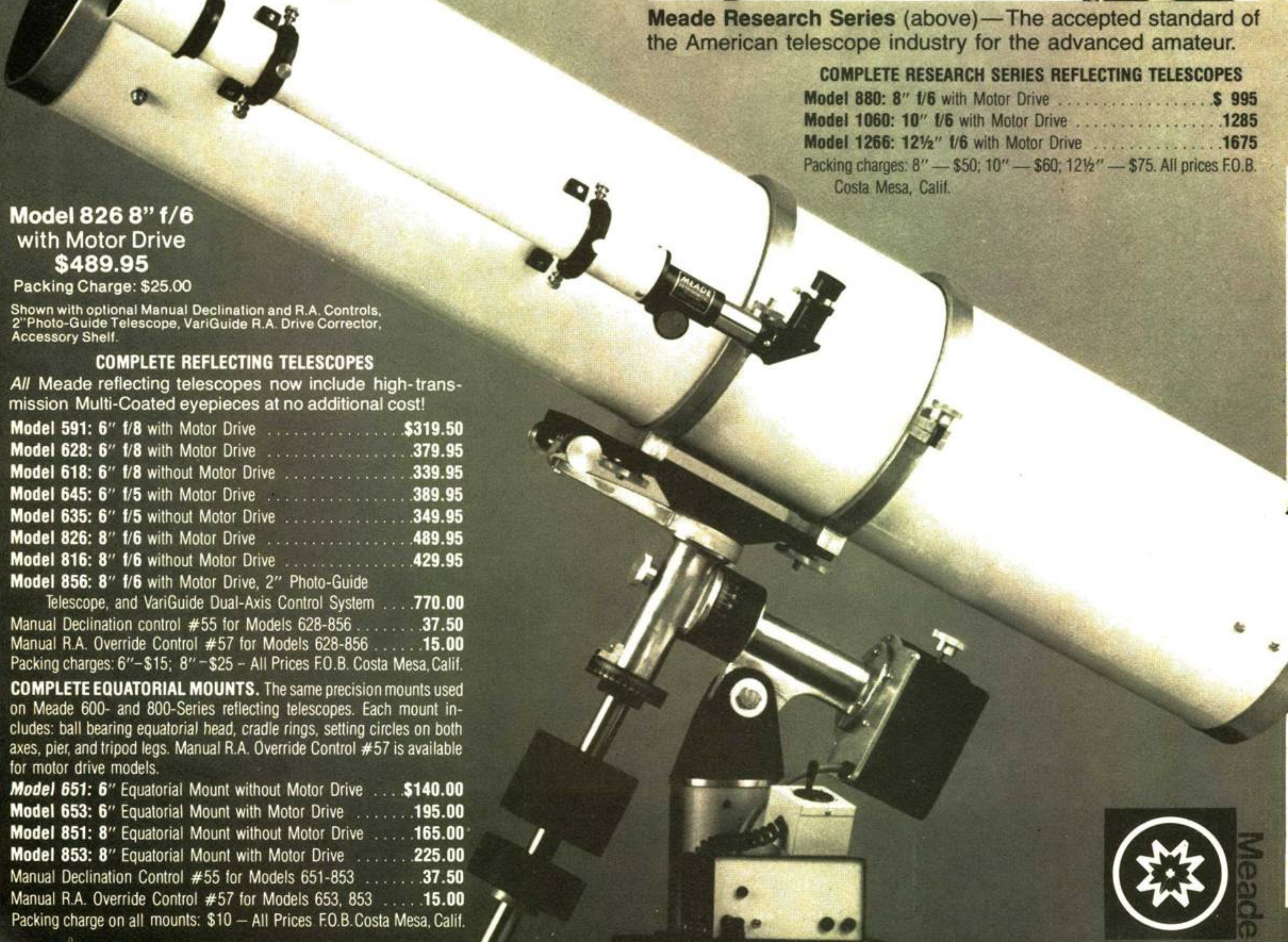

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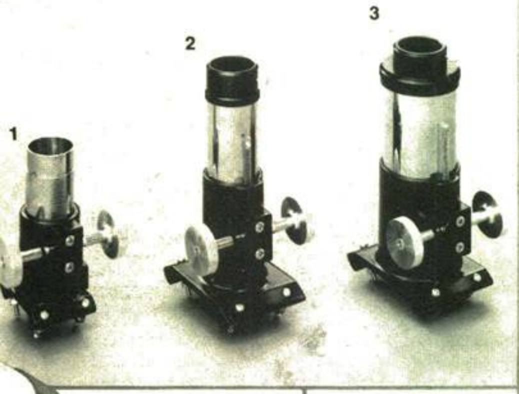

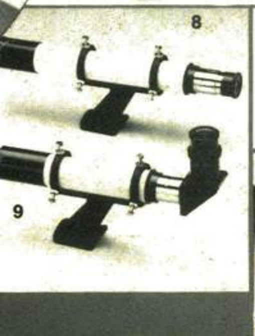

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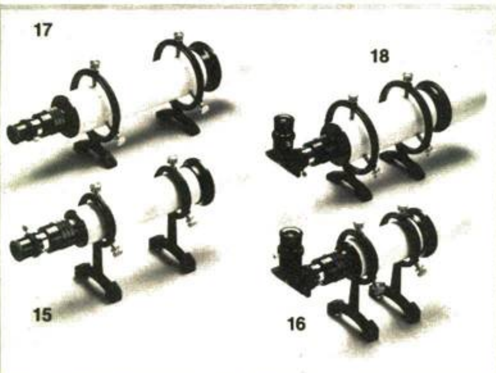

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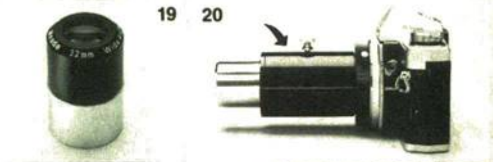

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photography in astronomy

a darkroom for astrophotography

Have you ever wished you could make fine photographs of the celestial glories you've seen so often in your telescope? If you're like many people owning a telescope and a camera, you may have wondered how to put the two together for maximum results. Well, you're not alone, and so we're beginning a bimonthly series on astrophotography — right from the fundamentals.

In this article we'll cover setting up your own darkroom, a project that is far from the immense, tiresome, expensive pain some people would have you believe it is — in fact, did you know you could probably set one up in your home right now for less than $300.

We'll get more specific later on, but in compiling your equipment list, always remember that the basic darkroom really doesn't have very many components, and there's only one pricey item among them. Set the initial cost against the thrill of making your own big glossy prints for about 30¢ each and it's pretty attractive, all in all.

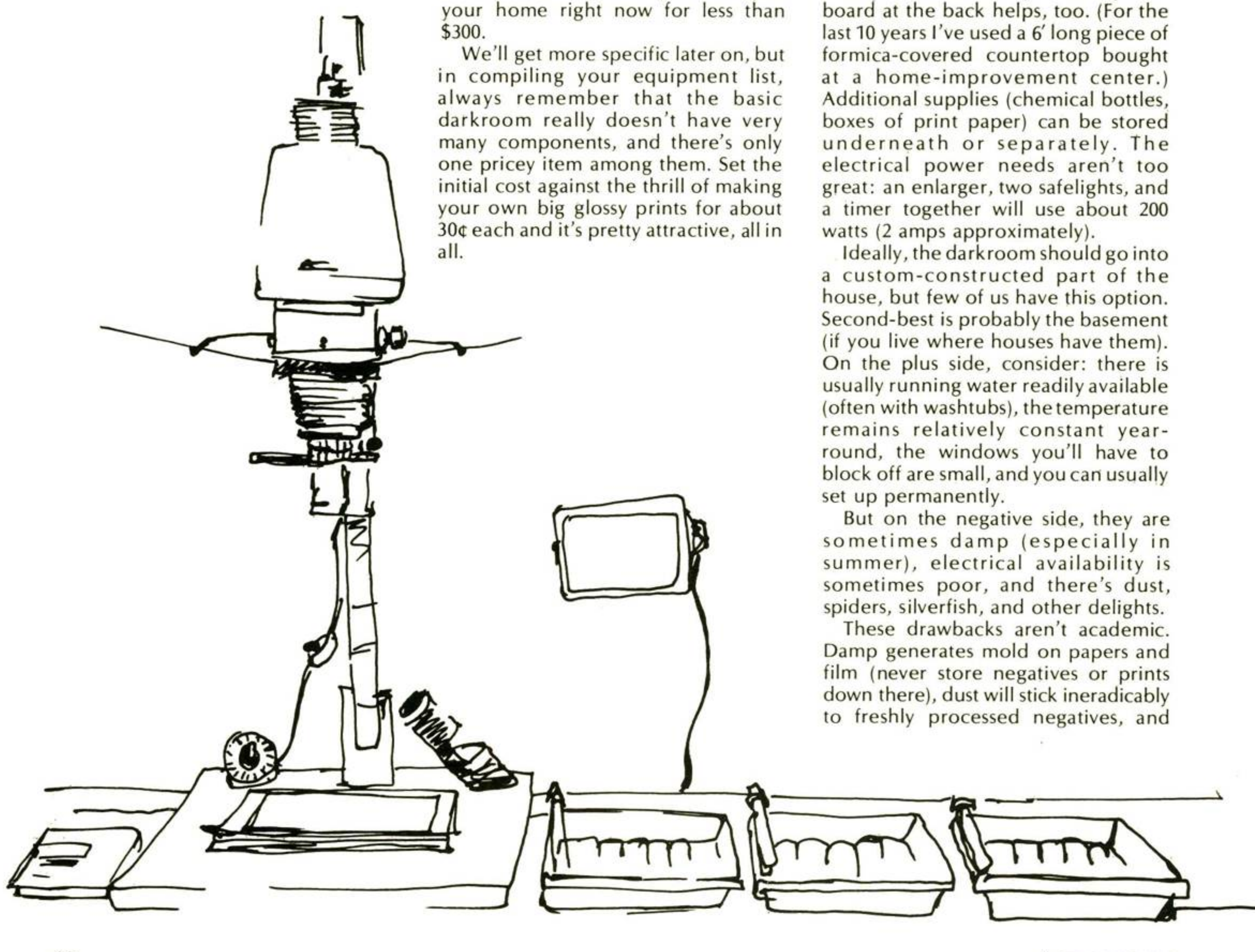
Where Am I Gonna Put It???

The first item to tackle is the matter of location, and this can be thorny in some cases. The space requirements are such that you'll want a counter about 18" wide and 5' long. This will hold an enlarger and three processing trays. It should be about 36" to 40" high and the surface waterproof; a splashboard at the back helps, too. (For the last 10 years I've used a 6' long piece of formica-covered countertop bought at a home-improvement center.) Additional supplies (chemical bottles, boxes of print paper) can be stored underneath or separately. The electrical power needs aren't too great: an enlarger, two safelights, and a timer together will use about 200 watts (2 amps approximately).

Ideally, the darkroom should go into a custom-constructed part of the house, but few of us have this option. Second-best is probably the basement (if you live where houses have them). On the plus side, consider: there is usually running water readily available (often with washtubs), the temperature remains relatively constant year-round, the windows you'll have to block off are small, and you can usually set up permanently.

But on the negative side, they are sometimes damp (especially in summer), electrical availability is sometimes poor, and there's dust, spiders, silverfish, and other delights.

These drawbacks aren't academic. Damp generates mold on papers and film (never store negatives or prints down there), dust will stick ineradicably to freshly processed negatives, and



insects will eat the gelatin in paper and film emulsions. You may have to install a dehumidifier if it's really damp. Dust can be defeated by finishing off the walls and ceiling of the darkroom, and insects can be controlled by the careful use of bug sprays.

Another common place to stash a darkroom is in a bathroom. These have almost all of the advantages of the basement — windows are apt to be smallish, lots of water available, you often have a power outlet — but the setup can seldom be permanent.

Many apartment-dwelling photographers rig up a board (out of ¾" ply, say) that fits over the bathtub, leaving a small space at the back where processed prints can be dropped down into the few inches of standing water in the tub below. This "holding tank" gets developed and fixed prints out of the way and starts the wash.

If the rig tends to wander, put a few 2 x 4 cleats on the bottom of the board so it stays put. Should your tub be too small to include the enlarger on the board with the trays — or if you don't fancy working on your knees — try it on the sink (beware of drippy faucets) or across the toilet (close the lid!). Also consider installing a fold-down table at the 36" to 40" height.

A third possible location is the kitchen. Here, the disadvantages become more constraining, but still not prohibitive. (In fact, some kitchens may be better than some bathrooms because you'll have more counter space.) Unfortunately, many are designed to be bright, sunny places — guaranteeing you headaches in devising a system to block and unblock those big, wide windows easily.

The same comments about multiple uses apply here as in the bathroom, but with the added urgency that food and photo chemicals DO NOT mix. Few of them are outright poisonous (at least in small doses), but what fool wants hypo in the meat loaf? Be sure all food is covered and put away before you start, and clean up *thoroughly* when you've finished.

Even more desperate souls have turned ordinary rooms into darkrooms — the Editor used a spare bedroom as his photo lab for 3 years. He built a large sink out of plywood and waterproofed it with polyurethane varnish (fiberglass would have been better). A large bucket under the drain sufficed to handle slop-overs from trays; washing was done in the bathroom.

Even a spare closet (if you have one) can be made into a darkroom provided it's deep enough to allow some shelves and you inside with the door closed.

How Dark Is Dark Enough?

O.K., once you've chosen a place, the next task is lightproofing it to the extent required. Strange as it sounds, you may not ever have to make the darkroom totally dark — remember, you'll probably be working at night. Since film and paper have different needs, you can arrange it so that your darkroom is "paper safe" without going to all the trouble of making it "film safe."

Paper processing is done by red or yellow safelight. The best test of whether your light leaks are severe enough to need fixing is to lay a sheet of photographic paper out on the counter where you'll be working. Cover part of it with a book or magazine, and leave it for 5 minutes. If there's any visible difference between the two parts when you develop the sheet, you've got an unacceptable amount of stray light. Start going around the room, plugging the leaks as you find them.

(Remember, too, that the leak may be visible only at countertop level. My darkroom once had a light leak that drove me nuts until I bent over, practically sticking my face into the developer — and finally saw it.)

With film, the requirements are a lot stiffer: "totally dark" has to be just that. A good test is to go in there and shut all the lights off. If you still can't see your hand in front of your face 10 minutes later, it's dark. Otherwise, get plugging.

Weatherstripping can be used along doorways, and so could strips of felt. Electrician's tape is convenient and opaque (but the adhesive gummily deteriorates with time); so are tinfoil, thick cardboard, several layers of black plastic garbage bag, and even wadded-up rags. (Though if you have to resort to rags and toweling, you might give some thought to something more permanent.) Large areas of window are best blocked with a sheet of plywood cut to size, painted flat black, and weatherstripped to a snug fit. (The Editor did this in that bedroom-darkroom of his.)

In some arrangements, it really isn't practicable to get your darkroom "film-tight." If so, for loading film into the developing tank (the one task needing complete darkness), you may wish to buy a changing bag. These are double-layer bags, made of very finely woven cloth and having a rubberized coating, with zippers at one end and two light-tight armholes at the other.

Using one is pretty simple, though it does take some practice: place the tank, film cassette, and bottle opener into the bag through the zipper opening. Having shut the zippers, reach in through the armholes and arrange your paraphernalia. Inside, where it's safely dark, you crack open the cassette, remove the film, and (deftly, now!) thread or wind it onto the reel of the developing tank. When the tank is loaded and closed, you remove your by now hot and sweaty hands from the bag, unzip the other end, and extricate the tank. Processing goes on in full room light with you pouring the chemicals in and out through the tank's light-tight spout.

Tanks, Paper, Bottle Openers, Bags?

All darkroom equipment falls into one of three classes: absolutely necessary, very nice to have, and superfluous luxury. There's little question about the first category, but you may find you disagree with me on the last two. This isn't really important, because you'll work out your own needs, anyway, and that's how it should be.

Film Processing. The necessities are: developing tank and reel(s), graduate, thermometer, funnel, chemical storage bottles, film clips, can opener, developer, stop bath, and fixer. Sounds like a lot, doesn't it? Bear in mind, though, that many of these are multi-purpose in that you'll use them in making prints, too.

Tanks come in plastic or stainless-steel versions, the plastic jobs having film reels included (they're a separate purchase for the stainless tanks). Make sure the top fits tightly if you get the stainless type, otherwise you'll slop chemicals all over the work counter and your hands. A plastic tank-and-reel goes for about $10, stainless-steel for $8-12 (tank) and $7 (per reel in 35 mm size).

The *graduate* is needed for mixing and apportioning the chemicals. You'll find good and bad plastic ones in the photo stores, but you can also use a measuring cup from the kitchen. (Just make sure it's clean when you're done...) If you go out and buy one, get the 1 quart (32 oz.) size. Prices run $5 to $10.

Your *thermometer* should have ±½° F accuracy, and should be easily readable. You'll pay $5-15 for a good one.

Funnels can be bought at photo shops, but hardware stores will have them cheaper; get a plastic one for about $1.

Chemical storage *bottles* in plastic can be bought at photo stores for about $4 (gallon), $1.50 (quart), but recycled glass juice and cider jars work fine, too, and you may have them already.

For *film clips*, use plastic spring-type clothes pins. A dollar spent at the supermarket will buy more of them than you'll ever need (wooden ones aren't good since they'll absorb a chemical residue over time).

Bottle opener? Well, leave the kitchen's alone and go get one for the darkroom; it's simpler than borrowing all the time. ($1, at most.)

Developer mix comes in quantities to make a quart ($1.50) or 1 gallon ($2.50). (The poor economy of buying small quantities is obvious!) Start off with a gallon mix of D-76 (Kodak). Kodak's D-19, necessary for the spectroscopic emulsions, comes in 1 gallon mixes for $3.

Stop bath (which neutralizes the developer and thereby prolongs the life of the fixer) costs $3 for a 16 oz. bottle. Start with Kodak's Indicator Stop Bath. Handle it carefully; this stuff is ferocious: ½ ounce of it mixes with one quart of water for use.

Fixers come in two types: ordinary and rapid. The rapid type is a concentrated liquid you dilute for use; the ordinary is a powder you dissolve. Mixes for 1 gallon are available for about $4 (rapid) and $2.50 (powder).

In the optional category are the aforementioned *changing bag* (for about $10) and a *timer* ($30 to $60). The bag's usefulness is your decision, but you will need something to time your processing. A watch with a sweep second-hand does fine, and naturally, a whole range of timers can be found in any photo store.

Print Making. Apart from the enlarger, you'll need 3 developing trays, a safelight or two, a contact printing frame, a washer, printing paper, and an additional chemical (a paper developer).

The *enlarger* is the biggest expense you'll incur in getting a darkroom. There's a nearly-infinite variety on the market, but all you need is a device that will blow up a 35 mm negative at least 8x and has a good sharp lens. The condenser type will provide crisper looking prints than the diffuser kind. Let your budget be the guide, but don't pinch pennies too tight on this item. A good enlarger will cost around $200, though you may get lucky.

Trays should be deep (at least 2") and get them 11" x 14" to start with as they should be one size larger than the maximum size prints you intend to make. (Few astro negatives will project larger than 8" x 10" with acceptable quality.) Three will cost you about $15 to $25.

Safelights come in red or yellow; yellow appears brighter to your eyes. In picking one out, look for good construction with longish cords and hanging or mounting brackets. Those little screw-into-the-light-socket jobs aren't very good, being fragile and dim. Expect to pay around $20.

The *contact printing frame* can be bought for $20, or you can go buy a piece of window glass at the hardware store for a dollar or two.

A plastic dish pan with a few small holes punched in the sides along the bottom will make a *washer* — or you can go out and buy one specially made for $10 to $15. (Later on in the series, we'll tell you how to use one to get properly washed prints.)

For *printing paper*, start off with a 25 sheet package of single weight, glossy finish, contrast grade 3. Cut it into smaller sizes for little prints and test strips. RC paper is perhaps best to start with, though prints made on it will go bad quicker than ones made on regular paper. $10 to $12.

The additional chemical is Dektol *paper developer* (by Kodak). It comes in quart and gallon mixes; get the 1 gallon size. (Stop bath and fixer are the same as for film.) $3.

In the two optional categories are print tongs, timer, easel, focuser, and dryer. The tongs may not in fact be optional if you're one of the many people whose skin is more or less allergic to photochemicals. If you get them, buy the best: look for a comfortable, firm grip and rubber tips. $4 for two.

Timers for making enlargements control the enlarger and give repeatable, consistently exposed prints, but again, your watch with a sweep second-hand will do to start with. $30 to $60.

Easels are handy, but four pieces of masking tape doubled over, one underneath each corner of the paper, do fine and give borderless prints as well. $25.

Focusers help you get the focus pin-sharp (well, as good as the enlarger lens allows), but I have always been able to get the film grain crisply focused without them. $10 to $50.

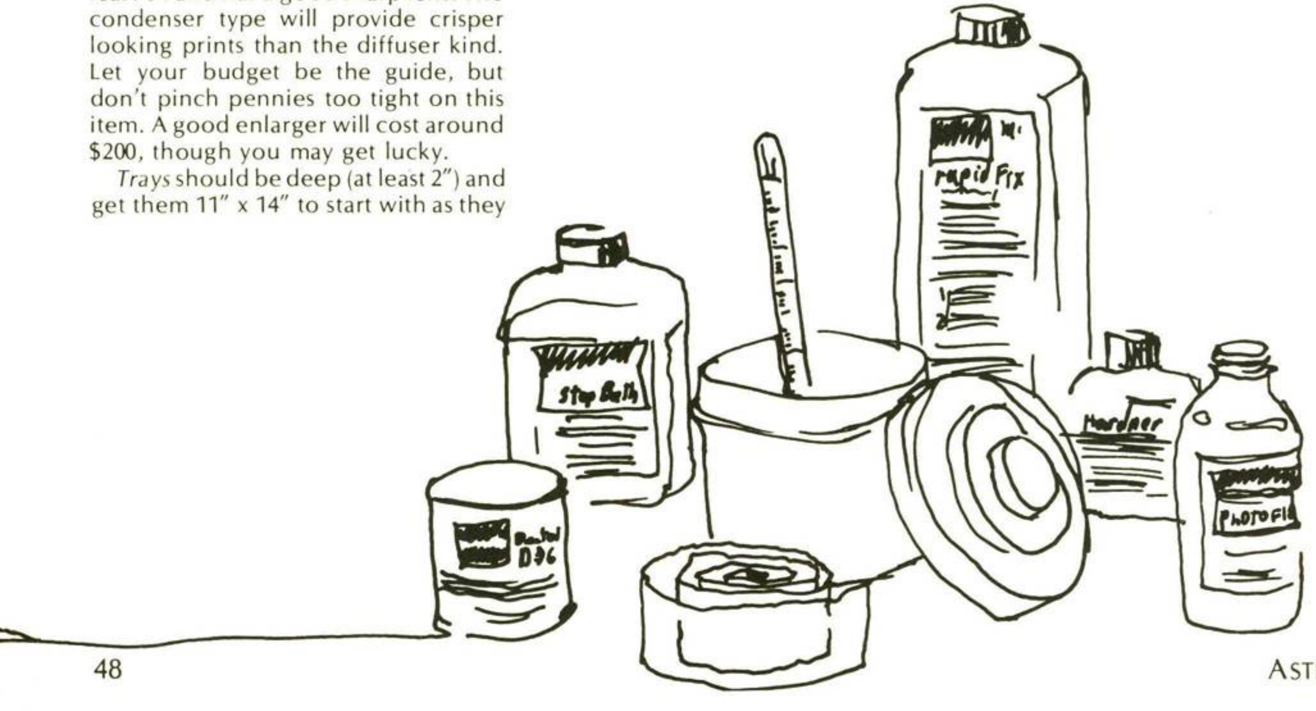
Dryers come in all types from spiral bound blotter books ($10) to electrically heated models ($25 to $60). The blotter books eventually absorb residue chemicals and contaminate succeeding prints, as do the cloths on the electric dryers.

Long ago I made a "hammock" out of a 3' by 10' piece of nylon screening (try a hardware store). The screening is stapled to two slats, one at each end, and slung from two convenient hooks in the ceiling. The prints are laid on face down and dry in the air. The hammock rolls up when not in use and, being made of non-absorbent nylon, can be hosed off from time to time to get rid of any residual chemicals.

General things for the darkroom might well include a rubber mat on the floor to ease the feet, a radio, a stool to sit on, a stereo, a bar — you name it, someone probably has it in a darkroom.

Next, we'll go step-by-step through the actual nitty-gritty of processing a roll of black and white film.

— Robert Burnham



what's my f/ratio?

equipment atlas

What's my f/ratio?

What do you mean?

Whenever you talk about telescopes, you give this f/ratio thing right after the aperture; you know: "6-inch f/5." Everybody nods knowingly, but I'm left scratching my head. What is this f-thing? What's it mean?

Well, the f/ratio is nothing more than the numerical ratio between the focal length of a telescope (or a lens) and its aperture. The focal length of that 6-inch f/5 is 30 inches. Similarly, the focal length of a 200 millimeter f/10 telescope is 2,000 millimeters.

Well, what about my telephoto lens? It's supposed to be a 200 millimeter, but it's no eight inches across. What gives?

Just to make life confusing, photographers never speak directly of aperture; when a photograper has a 200 mm lens, he's specifying its focal length, not its aperture. If he's got an f/4 lens, it has a 50 mm aperture. Clear?

So it's like a code?

It's jargon. F/ratio is just a quick and convenient American way of giving the vital statistics of a telescope. Europeans don't specify that way. Instead, they specify the aperture, a slash, then the focal length. Your 6-inch f/5 telescope becomes a 150/750 *Teleskop* in Germany. They're so metric they even drop the millimeters.

Well, why does f/ratio matter? Why's everyone making such a big deal of it? Skip the explanations and tell me straight: when I buy my next telescope, should I be getting an f/6 or an f/7? Which one's better?

Neither one is really better — they're just different. And really, you can't skip the explanation even if it's got a bit of math in it. Let's look at the basics. Do you know what "focal length" is?

Sure. It's the distance from the lens to the place where it makes a picture. The longer the focus, the bigger the picture. Right?

That's almost right, and it's true of simple lenses and mirror systems such as refractors and Newtonian reflectors. You can form an image of a distant bright object, such as the Sun or Moon, and measure the focal length directly with a ruler. If you measure the light path from the mirror to the image in your 6-inch f/5, you'll find it really comes out 30 inches.

Uh-huh. Then what about those stubby telescopes? How come they're f/10 and they're so short?

With compound optical systems, or systems that use several lenses, or a lens and a mirror, or several mirrors to form the image, the focal length can be amplified or magnified inside the telescope. The focal length of those telescopes is more accurately called the "effective focal length." Its effective focal length of 80 inches means it forms an image the same size as any lens or mirror with an 80-inch focal length. It's *as if* it were 80 inches long.

Geez, so it's f/10 because it's got an 8-inch front lens and an 80-inch effective focal length, huh? Pretty nifty.

Sure. You could make a Newtonian reflector or a refractor with the same specifications. Any 8-inch aperture and 80-inch focal length scope, with the same eyepiece, will give you the same magnification, you know, and each would have just about the same resolving power.

Magnification? What's the eyepiece got to do with it? I thought an eyepiece is to look through.

Well, the image the telescope forms has to be re-formed in your eye for you to see it. Eyepieces determine the magnification, or how many times closer and bigger an object looks. You just divide the focal length of the telescope by the focal length of the eyepiece. Here, put this 10 mm eyepiece (see where it says it's 10 mm?) in your 6-inch f/5. What's the magnification?

Well, uh, lessee, I guess I got to put it all in millimeters, huh? Uh, 30 inches times 25.4 is, um, about 750 mm. So it's 75x.

Sure. And in the 8-inch f/10, what will it give?

200x — see, got it right off. It's got a 2,000 millimeter focal length. So the same eyepiece gives me a different magnification in different scopes. Okay then, how come this resolving power thing is the same?

Magnification is how big you make the image. Resolving power is the amount of detail in the image. Whereas magnification depends on the telescope focal length and the eyepiece focal length, resolving power

exit pupil recommendations

4 to 7 millimeters	rich-field viewing, deep-sky objects
2 to 4 millimeters	general viewing
2 millimeters	resolution of eye just matches the telescopic resolution; lowest power to see all image detail
1 to 2 millimeters	lunar and planetary observing detail in deep-sky objects
0.5 to 1 millimeter	lunar and planetary detail

depends only on the aperture of a telescope — providing it has lenses or mirrors of good optical quality. The f/ratio doesn't have any effect on the resolving power.

So what's the difference?

If the telescope has a long focal length, then your eyepieces give higher magnifications than they do with a short focal length, but the actual amount of detail in the image is the same.

So how come I've heard that for good planetary detail the telescopes should have a big f/ratio? Shouldn't they both show you just the same thing?

They should. But with a short focus telescope you'd have to use awfully short focus eyepieces to get a high magnification. Most eyepieces with focal lengths much shorter than 6 or 8 millimeters are a bit difficult to look through. Besides, the awful truth, especially with home-built Newtonian reflectors, is that long focal ratio telescopes tend to have better optics because short focal ratio mirrors are quite difficult to make.

Ah-hah! So a long f/ratio is better?

Not necessarily. Just because they're tough to make doesn't mean that nobody can make really good ones. Lots of high quality short focus mirrors have been made. But long focus mirrors are easy — well, you know, above a certain f/ratio a mirror can be spherical instead of parabolic. They're really easy — practically anybody can make a good 6-inch f/10. But an f/5 — now that takes some skill!

Why bother with an f/5 then?

Remember, the short f/ratio gives you a shorter telescope. In addition, for deep-sky observing, where you want to use low magnifications, ordinary 25, 28, and 32 millimeter eyepieces are just perfect. If you're a confirmed deep-sky addict, then you'll prefer the low f/ratio.

Now just a minute. I've heard you get a brighter image with a short-focus mirror. Is that true, or is somebody putting me on?

Well, it's both true and not true, depending on just how you mean it. For astrophotography, it's strictly true, because the telescope forms the image that exposes the film. Mirrors (and camera lenses, too) with low f/ratios illuminate the film more brightly. Since there's more light, the photographic exposure can be quicker, so low f/ratio systems are called "fast." Follow?

Sure, or at least I think I do.

The fast short-focus mirror forms a smaller image with the light, so it's a smaller, brighter image. And a long-focus mirror forms a big, but dim, image.

Okay, maybe that works for nebulae. But what about stars? They're pinpoints no matter what the focal length, aren't they?

Right. In fact, if you want to photograph stars rather than nebulae, a long focus system is better. Since the background sky is dimmer, you can expose longer with a "slow" system and record fainter stars than you can with a fast mirror.

So those ultra-fast Schmidt cameras aren't all they're cracked up to be?

No, they're simply special instruments that are optimum for photographing large diffuse objects. Many astrophotographers aren't concerned with photographing faint stars; they're after nebulae. Schmidts are good for that. For taking pictures of globular clusters, where getting faint stars is the name of the game, Schmidts aren't the best.

I see, creeping specialization. You mean there's no one *best* telescope for photography?

Absolutely. In fact, there's no one "best" telescope for any purpose. You've got two scopes yourself, haven't you?

Sure. And my 6-inch f/5 is better for deep-sky observing, especially for exploring the Milky Way. Doesn't it give a brighter image than my f/10? It seems to.

Yes, for astrophotography. The focal ratio, you see, determines how bright the image is at the focal plane where the image is formed. But when you use a telescope visually, you use an eyepiece, right?

Yeah.

Well, the eyepiece transfers the light into your eye, so it also plays an important role in determining how bright the image looks. Since the pupil of your eye opens up to about 7 millimeters in the dark, the more of that 7 millimeters filled with light, the brighter the image in your eye will be. The size of a telescope's exit pupil is the focal length of the eyepiece divided by the telescope's focal ratio.

I never heard that before.

It's usually not put that way, but it's true. When you use that 28 millimeter eyepiece in your 6-inch f/5 telescope, the exit pupil is 28 divided by 5, or 5.6 millimeters. That pretty much fills the 7 millimeter pupil of your eye.

Well, then maybe I should get a 32 millimeter eyepiece and fill it a little better! After all, 32 divided by 5 is 6.4 millimeters, and I'd get a brighter image, wouldn't I?

A little, but probably not enough to notice. If that 32 mm is a wide-field design, such as an Erfle, what you would notice is the wide field. But very large exit pupils are tiring to look into because you have to keep centering your eye. Your 5.6 mm exit pupil is good enough. Aren't you happy with your 28 mm?

Sure, it's great!

Well, stay with it then. Any exit pupil diameter from 7 mm down to 4 mm or so will give you the rich-field effect.

What's this "rich-field" bit? Does it have anything to do with "RFT"? That's what my 6-inch f/5 is, isn't it? I know it's got a nice bright image!

RFT means "richest-field telescope." It's simply a telescope with a large exit pupil. The big exit pupil means the magnification is low for the aperture, so the field of view is more crowded

a focal formulary

D = diameter of the telescope's objective
F = the effective focal length of the telescope
f = the telescope's **f**/ratio
= **F/D**
E = eyepiece focal length
M = the magnification with a given eyepiece
= **F/E**
P = the exit pupil diameter
= **D/M**
= **E/f**
R = resolving power in seconds of arc
= **D/4.5** (when **D** is in inches)
= **D/115** (when **D** is in millimeters)

c = off-axis angle at which coma = 1 second of arc
= $16f^2$ seconds of arc in a Newtonian
d = "coma-free" photo field of a Newtonian
= $0.8f^2$ millimeters
A = maximum aperture for a given **f**/ratio (in mm)
= $f^3/6$ for a spherical Newtonian reflector
= $f^2/1.5$ for a "color-free" objective lens

with stars — it has a "rich field."

And what's that got to do with the f/ratio?

Most observers will call any telescope with an f/ratio around f/4 or f/5 an RFT. At those f/ratios, convenient and ordinary eyepieces give you the rich-field effect.

I'm just thinking — what about those gadgets that change the f/ratio? If they make my f/10 scope f/5, and I use this 20 mm eyepiece with it, I get a 4 mm exit pupil, right? But I get a 4 mm exit pupil with the 40 mm eyepiece that came with the telescope. It ought to give the same power, too. Is this some kind of scam?

They have a positive achromatic lens which converts the f/10 beam of light to an effective focal ratio of f/5. You're right, both your 40 mm eyepiece and the 20 mm eyepiece give the same exit pupil and the same magnification. The 40 mm eyepiece has a rather narrow field of view, and the 20 mm eyepiece gives a big wide field that's like floating in space. It doesn't have anything to do with the f/5 focal ratio, though.

It *is* nice, but maybe I should have gotten a wide-field 40 mm eyepiece instead.

It's hard to find one. Having a wide field requires a large field lens, which with a 40 mm focal length, simply can't fit into a standard 1¼" eyepiece barrel. That's why 2-inch diameter eyepieces are made.

How come they don't make catadioptrics and refractors short focus to begin with? I mean, why are they f/10 or f/15? That seems a bit "slow."

There's several good reasons. You can't get the kind of optical performance astronomers need if they're too "fast." With catadioptrics, the secondary mirror gets too big to be practical in a fast system, and that decreases the theoretical resolving power as well as blocking light. Fast refractors have bothersome chromatic aberration. A fast refractor still makes a good RFT, but it's not as good as an f/15 of the same aperture at high power. Remember, though, you can use long-focus eyepieces to make those "slow" refractors give you RFT performance.

If I read you right, then I can use any telescope like an RFT for deep-sky observing if I have the right eyepiece? Is that right — the f/ratio doesn't matter?

Partly. But remember, you want to be able to use convenient eyepieces for most of your observing. Comfortable eyepieces tend to lie in the 32 to 20 millimeter range, so for deep-sky observing, most observers choose f/ratios between f/4 and f/10.

So f/5 and f/6 make good all-around Newtonians, I guess. Weren't f/8s very popular a few years back?

There was less interest in deep-sky observing than there is today, and more interest in planetary observing where you need high magnifications. While an f/8 can give you a good 4 mm deep-sky exit pupil with a 32 mm eyepiece, it's also suitable for getting high magnifications with short focus eyepieces. It's still a fine all-around f/ratio. Just look at the equations.

So I'd get higher magnifications from the same eyepieces if my 6-inch f/5 was an f/8 or an f/10? Mars and Saturn wouldn't look so tiny?

Right!

But the f/5 has a shorter tube?

Absolutely. And for deep-sky photography, it's fast, yet it's not bothered much by coma.

Coma — who's that?

Coma is an optical aberration. It limits Newtonian reflectors because it makes stars look like little comets at the edge of the field. Coma depends inversely on the square of the f/ratio.

Say again, good buddy?

That means coma is four times worse in an f/4 telescope than it is in an f/8 telescope. With an f/6 Newtonian telescope, coma won't bother you at the edges of a 35 mm film frame, but with an f/4 Newtonian, it's starting to. At f/8, the coma-free field is getting pretty big. At f/10 it's huge.

But the faster mirror means shorter exposure times, doesn't it? My back gets stiff, and I want exposures to be short if I'm going to be guiding them.

Both f/5 and f/6 are pretty good compromises between exposure time and coma-free field. If speed is really important to you, then you could live with an f/4.

Hmm, f/4 scopes sound good for portability. How does this coma stuff affect the visual image?

You'll see fuzzy stars around the edge of the field. The coma blur from an f/4 mirror grows to about 15 seconds of arc only a degree away from the center of the field. But most eyepieces don't do their best at f/4 either, so the eyepiece may contribute equally to the blurriness.

Well, can you tell me *my* f/ratio?

What do you mean "*your* f/ratio"?

You know — *my* f/ratio. My eye's f/ratio!

Oh, gotcha. Wide open, you're f/2.4. You have a 17 millimeter focal length and a 7 millimeter aperture.

Okay. Thanks!

— *Richard Berry*

magnifications and exit pupils for common telescopes

telescope	eyepieces 40mm	32mm	25mm	20mm	15mm	12mm	8mm	6mm
4" f/8	20x 5.0	25x 4.0	32x 3.1	40x 2.5	53x 1.9	67x 1.5	100x 1.0	133x 0.8
4" f/10	25x 4.0	32x 3.2	40x 2.5	50x 2.0	67x 1.5	83x 1.2	125x 0.8	167x 0.6
6" f/5	--- ---	24x 6.4	30x 5.0	37x 4.0	50x 3.0	63x 2.4	94x 1.6	150x 1.2
6" f/8	30x 5.0	37x 4.0	48x 3.1	60x 2.5	80x 1.9	100x 1.5	150x 1.0	200x 0.8
6" f/10	37x 4.0	46x 3.2	60x 2.5	75x 2.0	100x 1.5	125x 1.2	187x 0.8	250x 0.6
6" f/15	56x 2.7	70x 2.1	90x 1.7	112x 1.3	150x 1.0	187x 0.8	280x 0.5	375x 0.4
8" f/5	--- ---	32x 6.4	40x 5.0	50x 4.0	67x 3.0	83x 2.4	125x 1.6	167x 1.2
8" f/6	30x 6.7	37x 5.3	48x 4.1	60x 3.3	80x 2.5	100x 2.0	150x 1.3	200x 1.0
8" f/8	40x 5.0	50x 4.0	64x 3.1	80x 2.5	105x 1.9	133x 1.5	200x 1.0	167x 0.8
8" f/10	50x 4.0	64x 3.2	80x 2.5	100x 2.0	133x 1.5	167x 1.2	250x 0.8	333x 0.6
10" f/5.6	36x 7.1	45x 5.7	56x 4.5	70x 3.6	96x 2.6	120x 2.1	180x 1.4	240x 1.1
10" f/8	50x 5.0	64x 4.0	80x 3.1	100x 2.5	133x 1.9	167x 1.5	250x 1.0	333x 0.8

ASTRONOMY IN FOCUS

Making It in Space

Sir / Scott Conklin (June 1980, In Focus) felt compelled to answer David Fabrizio's letter (January 1980) which had been written in response to Frederick Ordway's commentary (October 1979) on an AstroNews item in July 1979.

But Scott Conklin was upset. Dave had almost said the general public was stupid. And if he had gone that far, Scott might have sought to file a class action suit in behalf of the majority. You know, I'll bet the letters are stacked up knee deep around ASTRONOMY's editorial offices from those wanting to take on apologist Conklin.

Historically, the majority has always been wrong. The only times when the majority has been right are (1) accidentally or (2) for all the wrong reasons...and both of these instances usually assume the same profile.

The space program did fail, as others besides Fabrizio have said, because it ceased to be a good show and because it was swamped by radical aspects of human behavior which have nothing whatever to do with intelligence.

To be nice about it, as Ordway said, "The reasons...are varied and complex..."

Well, true...but how many times can Walter Cronkite say "incredible" before the glued tube majority changes channels in favor of *Charlie's Angels*.

Right now the majority is missing something which James Oberg has mentioned time and again. Unfortunately, Oberg does not have clout. The Soviets, who fail to recognize the human drive for freedoms of all sorts, are right on the mark this time: no more Sputniks. It alerts too many human emotions — in America, especially.

If the Congress and the President and the Defense Department and the Pentagon and a few others should suddenly explode in a frenzy of worried excitement over Soyuz II, then the excitement would communicate itself to the generally stupid public and...oh my God! look what I just done gone and went and said! I'm gonna be sued right down to my socks!

And so, to move ahead, the Soviets quietly go about making it in space, learning not only what it takes to stay there but, in the process, discovering many other things with earthside applicability. But they are careful. They don't want to spook the American public into thinking — or emoting.

In the meantime, with the NASA budget emasculated, scientists lie through their teeth to save their pet projects. They can't even trust one another because each is in the race to save his or her own project and paycheck. Human behavior, even amongst the brilliant, makes them look a little brainless.

Complex? Oh, hell no. Not much. But it explains itself. The human species may be the only intelligent species in this universe, or just one of the more primitive, but as one of the more primitive, the majority reflects an ominously popular wisdom by meeting all its problems with all the conventional approaches.

Because the Soviets no longer appear to humiliate us (because the majority is ignorant of what is *really* going on), the Congress gets the message and all but destroys the space program, which in turn causes the otherwise intelligent scientists, engineers, and technicians to pull all kinds of cuties to stay in business.

On a personal level, after all, a scientist or engineer is as human as any of the slavering majority. There is a home to be kept up. There's the wife, the kids, and bills to be paid. There is the prestige to maintain...so what's really wrong about pumping up a little flagrant baloney to keep the agency alive until Congress comes through with a little money for *real science*.

William Proxmire is one of the things wrong, of course. But human behavior, which spawns dumbness even amongst the otherwise highly creative and learned, is the true culprit. Since there is no known answer to human behavior, despite religion, cults and the new religion, psychology, the only answer is in science and, I suppose, its child, technology.

But they require a little effort to understand. The general public will work anything but the brain — except in the traditional and conventional areas, as accounting, economics, and such. And who cares?

John E. Dyer
Collinsville, OK

Colonizing the Moon

Sir / I wish to comment on "Return to the Moon" in the April 1980 issue. Many of the plans in this article seem to be ideas which are just concepts for the near future. It would probably take billions of dollars even to get the plans off the ground.

The idea of living on the Moon permanently is out of the realm of my imagination. I believe that we should not even try to colonize the Moon on a permanent basis. One reason is that we seem to corrupt the environment wherever we go. Why should we try to colonize the Moon when it was stated in the article that it would be necessary to import materials that would result in a change in the Moon's environment? My point is why should we start disrupting the Moon when we have already seen what our technology has done to the Earth? Why transplant this same environmental corruption to another heavenly body?

Delon Ottley
Union City, CA

Eyeing the Pleiades

Sir / An intensely interesting question was posed in the April 1980 issue: How many stars of the Pleiades can an owl pick out?

The owl's vision is, at most, 100 times more sensitive than human vision, which yields a visual limit of magnitude 11; such sensitivity can discern about 100 stars of the Pleiades. Assuming Flammarion to be correct in his calculations, the owl could see down to magnitude 8.9 had it evolved on Mercury; on Venus, 10.3 (a hypothetical inhabitant of Venus is a Cytherean); Mars, 11.9; Jupiter, 14.6; Saturn, 16; Uranus, 17.4; Neptune, 18.4; and Pluto, an incredible limit of 20, the equivalent of the 200-inch telescope on Mount Palomar! Such visual acuity can discern about 1400 stars of the Pleiades.

Michael Ferrio
Charlestown, RI

Miles vs. Magnification

Sir / I've often noticed that when people look at the Moon or planets through my telescope, they ask me "How far away does the Moon look?"

That's a good question! In fact, the apparent distance depends solely on magnification, not on aperture. So when you know what power a given eyepiece has with the telescope, you can easily figure out the apparent distance: just divide the real distance by the magnification.

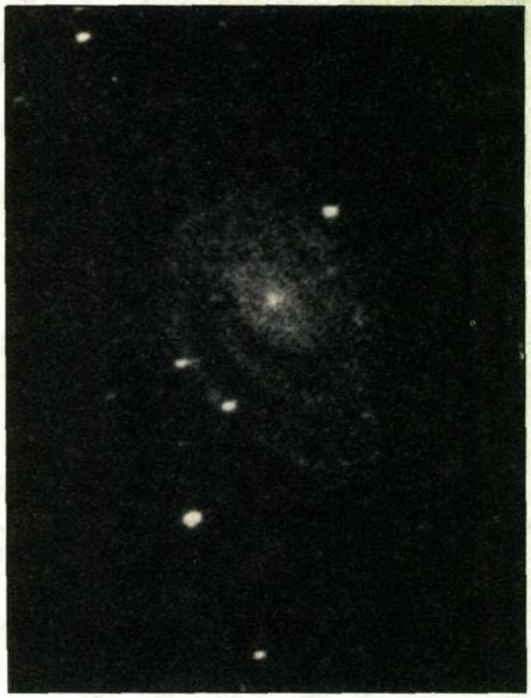
For example, look up the distance as given in Through the Eyepiece (make an estimate based on the date and the apogee/perigee distances), and divide it by the magnification. If the Moon is 230,000 miles away, with 105x it appears only 2190 miles away.

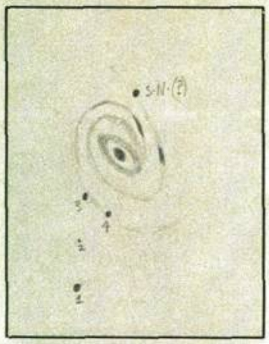
Another common question is "What power is your telescope?" So, to answer I now tell them how far "away" the Moon is — it means more to them than some dry figure like 105x.

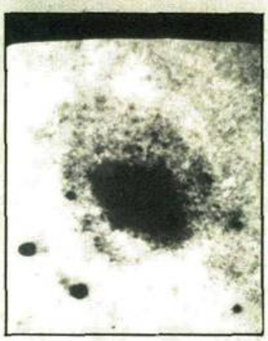
Norman Butler
Manhattan, KS

Ooops!

Through an oversight, Leo Henzl wasn't credited for the background photo used on pages 48 & 49 of the August issue.







behind
the scenes

supernova patrol

It appears that we've recently published a photograph of a supernova in ASTRONOMY without even knowing it! Our story begins with the photo in Thomas L. Dessert's article "An Album of Galaxies," in the May 1980 issue, page 47. Tom is an enthusiastic astrophotographer, making hundreds and hundreds of beautiful images of galaxies with his 10" reflector, some of which we ran with the story. Among them was a picture of NGC-5364, an 11th magnitude galaxy at 1950 coordinates R.A. = 13 55.0 and Dec. = +5°9' taken April 19, 1979.

After receiving the issue, reader Ian Cooper, of Palmerston North, New Zealand, wrote to us:

"The photographs with the article impressed me very much. I was especially attracted to the delicate whorls surrounding NGC-5364. I was so impressed, in fact, that I thought it would bear comparing with a large observatory photo. I sought the desired picture in *Burnham's Celestial Handbook*, volume III, page 2084. After a short time, I noticed a pretty bright star on the southern edge in Mr. Dessert's picture was not in the *Handbook* photo."

Mr. Cooper enclosed a sketch showing the location of the star. Robert Burnham of ASTRONOMY's staff (and no relation to the author of the *Handbook*) and I realized, as had Mr. Cooper, that that star could be a supernova. But was it still there?

First Robert checked the *Lick Observatory Sky Atlas*, a beautiful photographic star atlas. The "guest star" was not present. Then he checked the I.A.U. announcement cards, where discoveries such as supernovae are regularly reported. No mention of a supernova in NGC-5364. Many phone calls to Mr. Dessert's number convinced us he must be out of town. We next contacted Ben Mayer, a Los Angeles amateur who is now operating an amateur supernova patrol in conjunction with his PROBLICOM nova search program. Ben promised to get a photo of 5364 as soon as he had a clear night. After nights of clouds, the clear night came. The verdict: the star isn't there now.

Is it, or was it, a supernova? At this point, with this issue of ASTRONOMY going out the door in a few days, we don't really know for sure, but we'll continue the story next month....

Sincerely,

Richard Berry

Richard Berry

ASTRONOMY REVIEWS

Catalogue of the Universe
Paul Murdin and David Allen
Original photographs by David Malin
256 pages (illus.), hardcover, $15.95
Crown Publishers, Inc. (1979)

If *Catalogue of the Universe* were true to its title, it would be a formidable book — indeed, even if limited to only its subtitle: "a survey of the most familiar and extraordinary objects in the cosmos." Murdin and Allen have put together a highly interesting catalog of objects, but they are betrayed by too many so-so photos, some typos and a mediocre text. Yet the book remains interesting, if one can keep from being too distracted by its shortcomings.

The authors are top-flight astronomers, and their associate in this volume, research photographer David Malin, is superb in his field, too. Readers of ASTRONOMY are familiar with his work (see "Exploring the Image," November 1979, "Southern Skies Explored," February 1980, and "The Colors of Deep Space," March 1980).

To start with, the structure of the book is intriguing, and better yet, it works. The authors have arranged their "familiar and extraordinary objects" in order of decreasing size/complexity, from "The Universe of Galaxies" to "Stars and Nebulae" to "The Solar System." The first segment includes clusters of galaxies, unusual interacting galaxies, quasars, X-ray galaxies and radio galaxies, and the more familiar and bizarre members of our own Local Group. It ends with a look at our own Galaxy, including views of its center (Sagittarius A) in visible and IR light, and the galactic pole.

In "Stars and Nebulae" Murdin and company give fascinating glimpses of a variety of variable stars, multiples, associations, clusters, dust and gas clouds both familiar and obscure, and finally a look at some endpoints of stellar evolution.

"The Solar System," the final section, is the most familiar and, to this reviewer's mind, least interesting. The photos and accompanying text could just as easily be found in any of the other many popular astronomy books on the market today.

The most signal success of this book is the quality of the color photos. They are, with few exceptions, stunning. Particularly striking are the delicate blue tints of the two Magellanic Clouds; the Rosette Nebula, a luminous rose cloud-ring studded with stars; a wispy, blood-red Vela Supernova Remnant; an unbelievable reconstruction, via speckle interferometry, of the face of Betelgeuse; and a brilliant X-ray photo of the face of our own Sun.

Some of the black and white photos are quite different from the run-of-the-mill photos seen in similar volumes. Malin used a special masking technique to bring out hidden details, and the results are evident in the photos of the Orion Nebula (page 104), the Lagoon Nebula (pages 108 and 109), and the Rho Ophiuchi dark cloud (page 134).

Unfortunately, the rest of the photographs do not meet this quality; most are much too small, and do not have enough contrast to them to be interesting or helpful to the reader. In some cases, such as the black and white photo of Betelgeuse on page 91, a color plate is reproduced in black and white with severe loss of quality. Even where the quality is good, that's laziness. Couldn't the authors have found another photo, meant to be black and white, to use? Finally, there are instances of a photo used in a black and white mode only, when it should have been a color plate: witness the radar map of Venus on page 192. The definition is so poor as to be useless.

The accompanying text is average at best, and marred by some typos and occasional inaccuracies; on page 182, the authors refer to two photos of Pluto, taken a day apart, showing its movement through the sky. The photos, on the following page, are clearly labeled "January 23" and "January 29, 1930."

And yet...and yet. There are the marvelous photos of the Orion and Lagoon Nebulae, the incredible color plates, and, indeed, the many "extraordinary objects" Malin, Allen,

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and Murdin have chosen to include in this book. I cannot honestly recommend *Catalogue of the Universe* as a "must" purchase. But many may find it to be a worthwhile optional buy for their astronomical library. *Joel Davis.*

Astronomy and Astrophysics Abstracts, vol. 25
S. Boehme *et al.*, eds.
871 pages, hardcover, $66
Springer-Verlag (1979)

Access to the current published astronomy literature is provided by this semiannual series. Hardly a purchase for individuals, it nevertheless is worth browsing through in the library if you're interested in knowing what's been written on any astronomical topic. Volume 25 covers the first half of 1979's output; it has abundant indexing.

Light Scattering by Irregularly Shaped Particles
Donald W. Schuerman, ed.
334 pages, hardcover, $39.50
Plenum (1980)

A compilation of technical papers on a subject of importance to astronomers and planetary physicists.

Asteroids
Tom Gehrels, ed.
1181 pages, hardcover, no price given
University of Arizona (1979)

This fine, fat volume contains papers by just about everyone working on asteroid problems. The material is technical, but well-written and very comprehensive. If you want to learn what's currently known about asteroids, here's where to begin.

Guide to the Bright Planets
David Chandler
52 pages, paperback, no price given
Astroscopics (1979) [order from the publisher at 5617 Hawthorne St., Montclair, CA 91763]

Using formatted computer printout, Chandler shows where the Sun and naked-eye planets will be found along the ecliptic for the years 1980 to 2025 inclusive.

Ninth Texas Symposium on Relativistic Astrophysics
Juergen Ehlers *et al.*, eds.
599 pages, hardcover, $105
New York Academy of Sciences (1980)

The "Texas" Symposia (so-called because the first was held there) are where astronomers, observational and theoretical, can meet to trade ideas and results that develop our understanding of processes violent, large, or rapid enough to involve relativity. This is a reprint of the papers given at the 9th meeting at Munich, Germany, in late 1978.

The Planet Pluto
Anthony J. Whyte
147 pages, hardcover, $17.50
Pergamon Press (1980)

Beginning with Herschel's accidental discovery of Uranus 199 years ago, Whyte tells first the story of how the search for Pluto developed, and then how our knowledge of it has grown since it was discovered 50 years ago.

The History of the Telescope
Henry C. King
456 pages, paperback, $8.95
Dover (1980)

Long out-of-print and fetching very high prices among the used-book dealers, King's *History* is once again available for the general reader. Still the definitive work, it surveys in copious detail over 400 years of telescopes.

Life in the Universe: the ultimate limits to growth
William A. Gale, ed.
121 pages, hardcover, $12.50
Westview Press (1979)

In five chapters, 5 authors discuss the potentialities, likely developments, and consequences of space exploration and settlement. (This is part of the AAAS symposium series.)

Radiative Processes in Astrophysics
George B. Rybicki & Alan P. Lightman
382 pages, hardcover, $29.95
Wiley-Interscience (1979)

Rybicki and Lightman of the Harvard-Smithsonian Center for Astrophysics have written a textbook with practice problems aimed at the last-year undergraduate or first-year graduate student.

Galaxies and Quasars
William J. Kaufmann
226 pages, hardcover, $14; paperback, $7.50
W.H. Freeman (1979)

Completing the trilogy of *Stars and Nebulas* and *Planets and Moons*, this book covers galactic and extragalactic astronomy for the educated layman.

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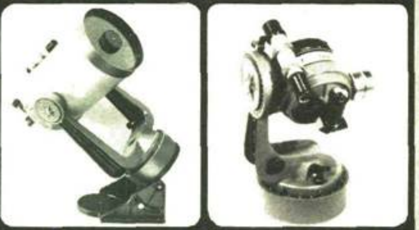

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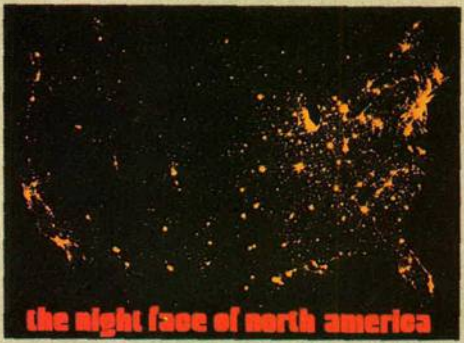
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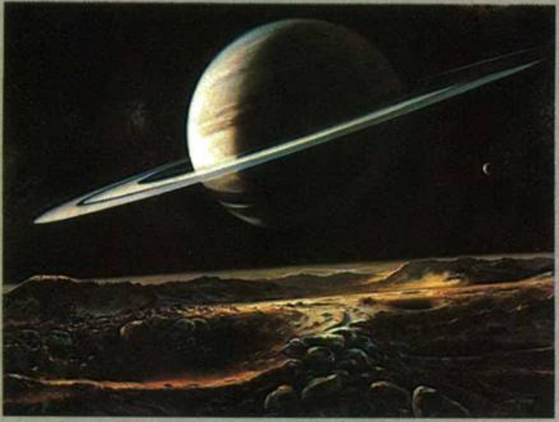

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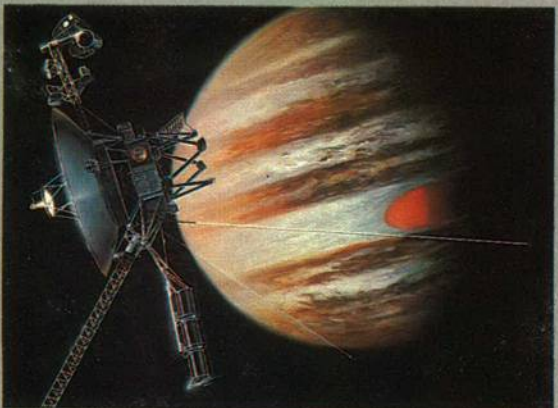

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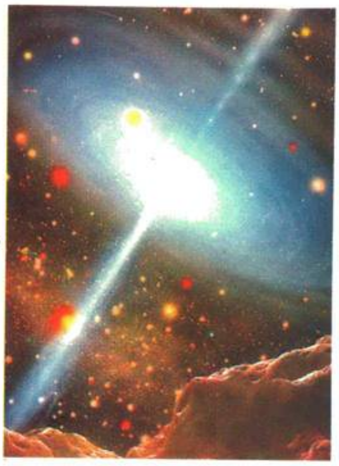

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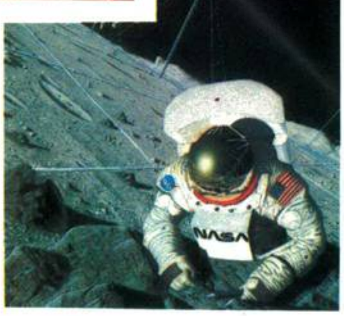

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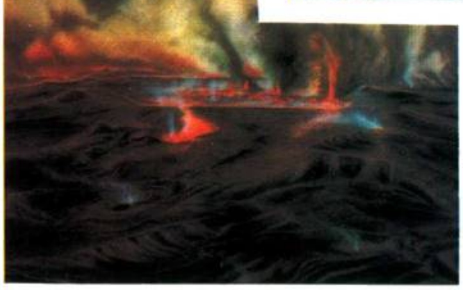

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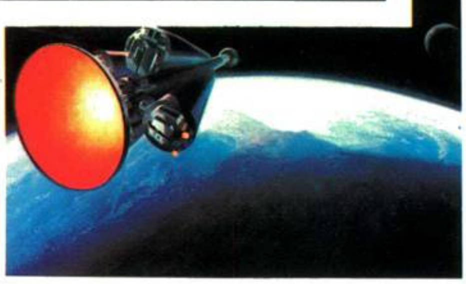

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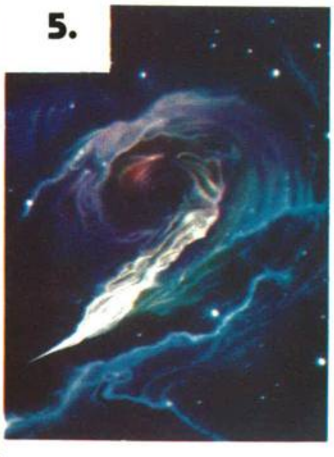

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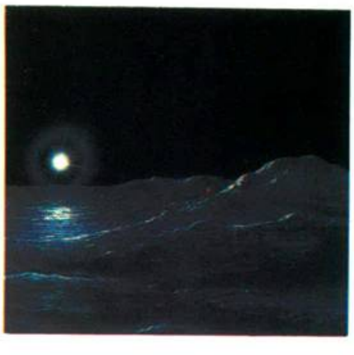


AstroNews

Earth May Once Have Had Saturnlike Ring

The possibility of a cosmic catastrophe with profound terrestrial impact accounting for unexplained prehistoric events has recently been gaining credibility among the scientific community. (See "Extraterrestrial Climate Threats" in last month's issue.) Now a NASA scientist has proposed that a huge volcanic eruption occurring on the Moon some 34 million years ago resulted in a giant earth-circling ring similar to the rings surrounding the planet Saturn.

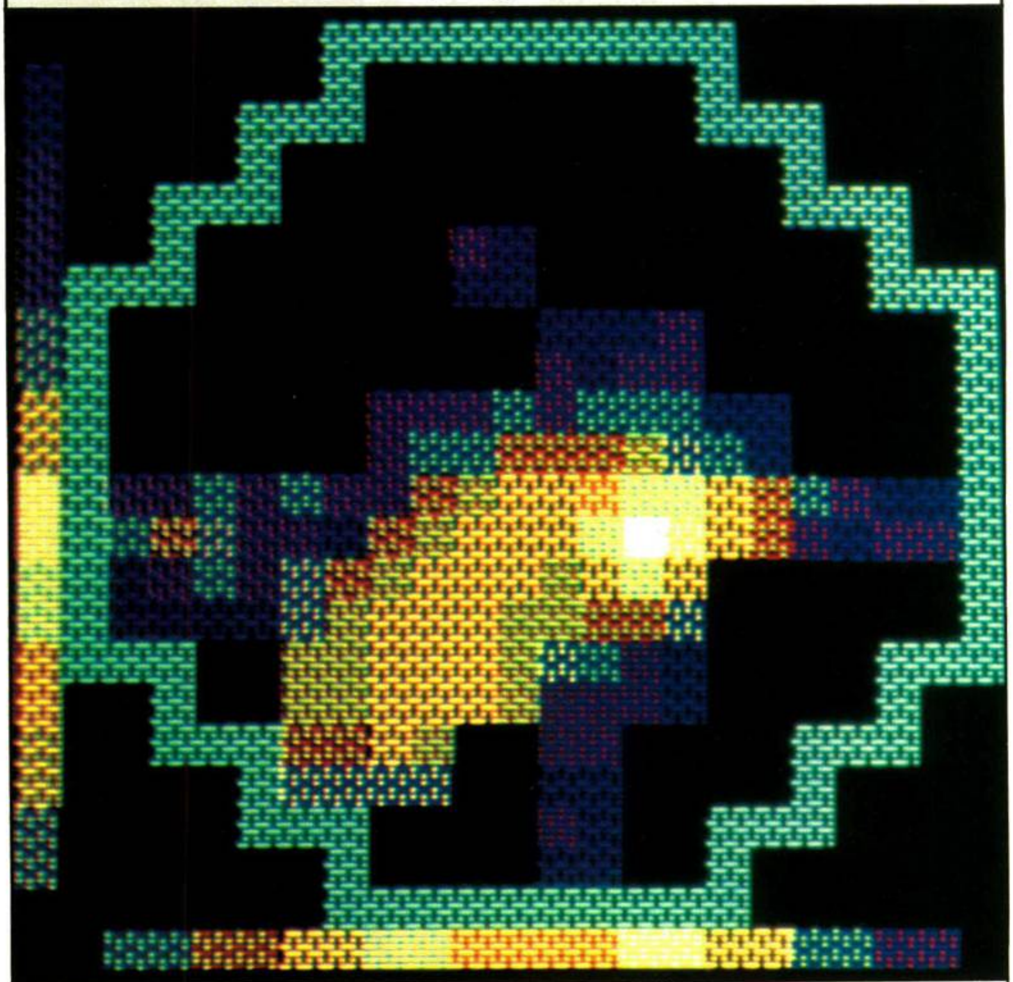
Dr. John A. O'Keefe, of the Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center in Greenbelt, Maryland, calculates that the ring, composed of tektites (glassy meteorites), lasted one to several million years. The shadow of the ring on Earth's surface would have caused dramatic climatic changes in the temperate zones.

The sudden climatic change 34 million years ago has been known to geologists for many years as the terminal Eocene event. The Eocene era represents the earliest part of the Tertiary period in the Earth's geological history. The terminal Eocene event is considered to be the most profound climatic change to have occurred during the entire Tertiary period between 65 million and 2 million years ago. (A similar episode about 65 million years ago, which resulted in the extinction of the dinosaurs and numerous other species, is called the Cretaceous-Tertiary extinction.)

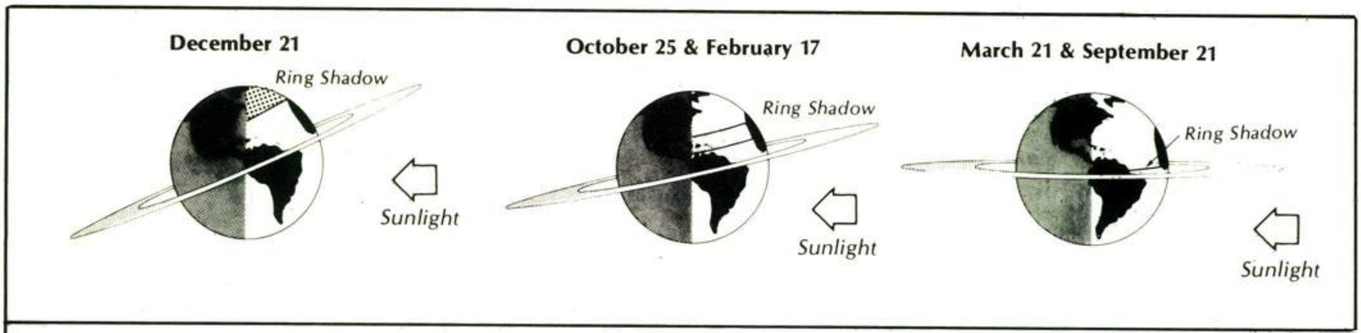
Through botanical studies, geologists already had found that temperature changes occurred at the end of the Eocene, but until now there has been no acceptable explanation for the occurrence, according to O'Keefe. During the terminal Eocene event, he explained, winter temperatures in the northern hemisphere dropped approximately 20 degrees Celsius (35 degrees Fahrenheit).

The basis for O'Keefe's belief lies in the fact that the biological changes coincide quite accurately with a massive fall of tektites from outer space. While the precise origin of the tektites has not been established, O'Keefe thinks that they might have come from an eruption on the Moon. Studies of the tektites, he said, show that some of them have similarities with rocks brought back from the Moon by American astronauts in the NASA Apollo program. He suggests that as much as 25 billion tons of lunar volcanic debris reached the Earth's neighborhood. Some of these tektites crashed into the Earth, leaving a path or strewn field extending at least halfway around the Earth, from the eastern United

X-Raying the Sun



This photo shows a solar flare as recorded on April 30, 1980 by the Hard X-Ray Imaging Spectrometer aboard the Solar Maximum Mission (SMM) spacecraft. The flare, which covered an area of 2.4 million square miles of the Sun's surface (an area much larger than Earth), marked the first instance in which the SMM scientists have been able to jointly collect and analyze data on the actual birth of a solar flare from a number of experiments aboard the spacecraft. In the image, the Sun's limb crosses slightly inclined from upper left to lower right through the center of the field of view, the solar surface being in the upper part. A very bright area of some 10,000 miles diameter appears at the limb, with an X-ray "tongue" extending downward about 25,000 miles. The temperature appears to be typically about 15 million degrees. According to SMM scientists, "The data strongly suggest that a low-lying magnetic loop filled with hot gas became excited, rose in altitude, and collided with a higher magnetic arch. It is the collision of these two magnetic arches which appears to have initiated the flare." NASA photo.



A ring around the Earth would cast a moving shadow as the angle of sunlight changed with the seasons. This shadow would make the winters substantially colder. The above illustrations show the effect on the northern hemisphere.

States westward across the Pacific to the Philippines.

But O'Keefe, writing in the May 29, 1980 issue of *Nature*, also suggests that the tektites which missed Earth went into orbit around our planet and organized themselves into a ring like the rings around Saturn. Once formed, the ring, extending from 4000 to 12,000 miles above the equator, blocked out the rays of the Sun in the northern hemisphere in the winter, due to the Sun's location below the plane of the equator. Such a ring, O'Keefe calculates, would have cut off 75% of the sunlight reaching Earth in the temperate latitudes during winter. Thus the shadow cast by the ring resulted in a drastic lowering of winter temperatures.

The ring then disappeared, O'Keefe believes, when forces in space such as the pressure of sunlight and the drag of the tenuous outer atmosphere, pulled the particles out of the ring. They were pulled either downward into the atmosphere, where some burned up and others fell to Earth, or upward into space away from the Earth.

The damage, however, had been done. Five abundant species of radiolaria, which can only live in warm water, died out suddenly at about the same time the tektites struck the Earth. This is known because the extinction is recorded in the same oceanic sedimentary layers where the tektites are found. Other evidence also indicates that the winters in the northern hemisphere became much colder at about the same time.

Coincidentally, but reflecting the present vogue in postulating cosmic catastrophic events, M. Ruderman and J.W. Truran of the Institute of Astronomy in Cambridge, England, have proposed that a nearby supernova could result in the transfer of significant amounts of lunar dust to Earth. Writing in the March 27 issue of *Nature*, the authors point out that such a supernova, which may be expected to occur within a few tens of light-years of our solar system every hundred million years or so, would emit an intense gamma-ray pulse. They suggest that the top centimeter of lunar soil could be expelled from the Moon by the gamma-ray pulse, with a significant amount of the dust eventually captured by the Earth to settle down through the atmosphere — with a variety of environmental effects. Ruderman and Truran do not, however, discuss the possibility of the ejected lunar dust forming a temporary ring around the Earth in the manner suggested by O'Keefe for lunar volcanic debris.

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A New Binary Pulsar

One of the world centers for pulsar discovery and research is the radio astronomy department at the University of Massachusetts in Amherst. Here astronomers have found two-thirds of all known pulsars, now numbering 327. Recently a U. of Mass. graduate student, Peter R. Backus, announced the discovery of a rare type of pulsar, a binary pulsar.

Currently only three binary pulsars are known, and number three promises to be a unique research tool for astrophysicists.

According to Backus, the pulsar was first identified by Marc Damashek, another U. Mass. graduate student. He was conducting a northern sky survey which revealed 25 new pulsars. A year later, during the summer of 1979, Backus began observing the pulsar and quickly realized something was unusual.

"We were using NRO's 300-foot radio telescope at Greenbank, West Virginia. The first readings of the pulse rate were much longer than Damashek's original estimate. No instrument error was found so we knew that something else was affecting the pulse rate," reports Backus.

By carefully measuring cyclic variations in the pulse rate it was determined that the pulsar was orbiting a common center with a close companion star. Binary stars are not uncommon but a binary system surviving a supernova explosion with only 770,000 miles separation is baffling.

The pulsar, designated PSR 06554+64, completes one orbit in 24 hours 41+ minutes. The orbit is almost perfectly circular. Its eccentricity is .0003 compared to Earth's value of .0016.

Backus pointed out that most known pulsars are moving quickly through space, indicating that the supernova explosion that created them forced them out of their original orbit. How did the companion star achieve such a perfect orbit? The answer, Backus feels, will come when the pulsar's companion is positively identified.

By checking with coordinates from the radio telescope, two optical stars have been identified as candidates for the companion. According to Backus, one is a red M dwarf and the other is a blue dwarf. The mass of the dwarf companion is estimated to be 0.6 to 0.8 solar masses and that of the pulsar about 1.4 solar masses.

The binary is about one thousand light-years distant and lies in the constellation Camelopardalis. The massive star that became a supernova was reduced to a very small but massive neutron star about 2 million years ago.

Backus was asked which dwarf is most likely to be the companion. "Because the orbit is so circular I feel it is the red M dwarf. It would have a more extended atmosphere that may have acted as a buffer on the pulsar's motion during the last two million years. This would probably eliminate any eccentricities of its original orbit."

Beyond learning more about the creation of neutron stars and pulsars, PSR 0655+64 may have a unique use. The

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pulsar may be eclipsed periodically by the dwarf. Further monitoring will be necessary, but if true, the eclipses will allow direct measurement of another star's outer atmosphere.

"We can observe frequency fluctuations of the pulses after they have passed through the dwarf star's outer fringes," said Backus.

X-ray emissions are also being looked for by researchers using the Einstein (HEAO-2) satellite. If matter from the less massive star impinges on the pulsar's surface, it should produce X-rays. Positive results were reported this past spring, but by late May more refined data showed the source was unrelated to the binary. X-rays probably are coming from the system, so the search will continue.

"Our current knowledge of the pulsar binary is still very preliminary. What is really needed is 24-hour-a-day monitoring. Because the orbital period is close to our day, the same point of the orbit is observed at the same time of day. We hope to interest other radio astronomers using northern latitude telescopes," concluded Backus.

X-Rays From Jupiter

In recent decades, Jupiter, the solar systems's largest planet, has been revealed as a center of vast electromagnetic power, emitting radio waves, bursts of electrons, and other forms of energetic radiation. Now scientists studying data from NASA's second High Energy Astronomy Observatory (HEAO-2) have confirmed the emission of X-rays from Jupiter. The giant planet thus joins Earth as the only planets currently known to produce X-rays — although it is expected that any planet with a magnetic field and surrounding radiation belts will emit X-rays.

The findings are expected to add to our knowledge concerning the enormous belts of trapped energetic charged-particle radiation which surround the giant planet, and could provide new information on the surface composition of Jupiter's large moons.

The X-ray emission was confirmed by a team of scientists led by Dr. Albert Metzger of the Jet Propulsion Laboratory in Pasadena, California. The observations were made using the focusing X-ray telescope on the Earth-orbiting satellite. The telescope must operate in space because X-rays cannot penetrate far enough into Earth's atmosphere to be observed from ground-based X-ray telescopes or other instruments.

Four different X-ray instruments, each performing a specialized function, can be positioned at the telescope's focus — including the Imaging Proportional Counter which was used for the Jupiter observations. In the three separate six-hour periods during which Jupiter was imaged, X-rays in the energy range from 100 to 2000 electron-volts were observed at an average rate of one every 100 seconds. While this doesn't sound like very much, actually it implies that hundreds of quadrillions of watts of power are being pumped into the jovian system by highly energetic electrons moving in Jupiter's immense magnetic field.

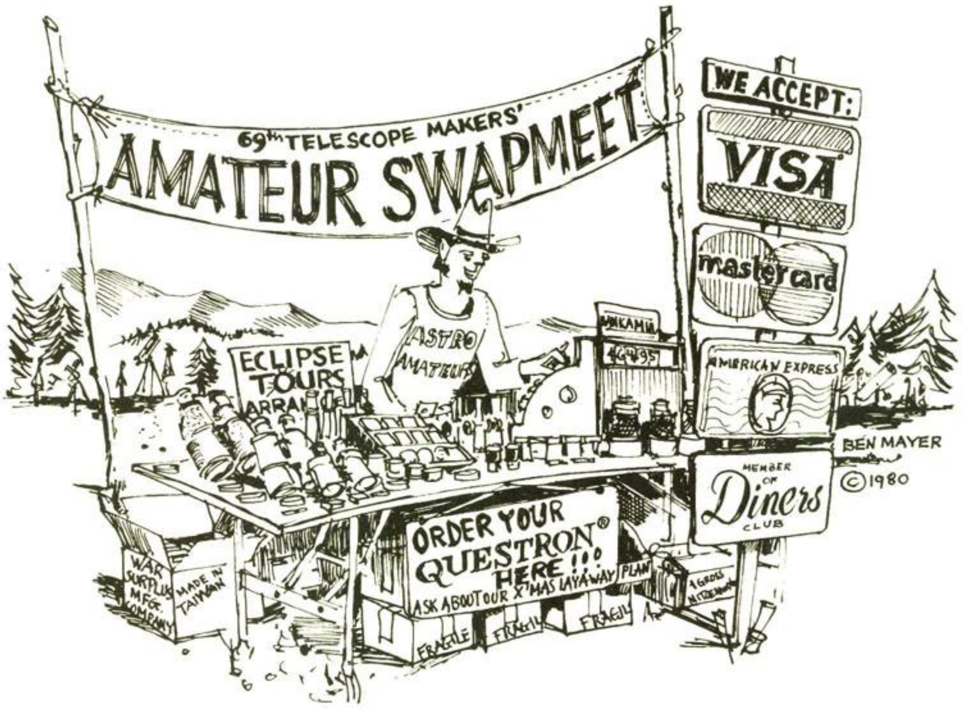
Energetic electrons and ions produce X-rays when they are absorbed in the atmosphere of Jupiter, on the surfaces of the planet's moons, or on the newly-discovered rings around the planet.

According to Metzger, X-rays may be produced in Jupiter's atmosphere the same way they are produced in Earth's, by energetic electrons that spiral into the atmosphere from the trapped radiation belts as a result of interactions between the trapped particles and the planet's magnetic field. The energetic particles collide with atoms and molecules in the atmosphere, producing a broad band of radiation that includes visible aurorae, ultraviolet light, and X-rays. Observations of Jupiter's aurorae by the Voyager 1 and 2 spacecraft suggest that the X-rays, like the ultraviolet light, emanate from the planet's polar regions.

The X-ray observations are an indication of how much power it takes to maintain the intense radiation belts in Jupiter's magnetosphere. The belts are contained by the action of Jupiter's strong magnetic field, which also acts to shield the region around Jupiter from the influence of the solar wind. From the X-ray brightness observed, scientists calculate that nearly one quadrillion watts of power are dissipated by energetic electrons absorbed in the Jupiter system. In order to maintain the radiation belts, an equal amount of power must be supplied from the planet's rotational energy and from the force of the solar wind.

It is also possible that X-rays are produced by energetic ions and electrons bombarding the surfaces of satellites orbiting within the jovian radiation belt. Observation of these X-rays could be used to determine the composition of the surfaces of the satellites Io, Europa, Ganymede, and Callisto.

Saturn, with its weaker magnetic field and radiation belts, has not yet been observed to emit X-rays. The Pioneer 11 spacecraft, which flew by Saturn last September, failed to detect X-rays, but more sensitive detectors aboard the Voyagers may reveal them. On the other hand, it may be that Saturn's many moons keep the saturnian system relatively "clean" of high-energy electrons by "sweeping" them up.



Exploring the Ultraviolet

New findings from the International Ultraviolet Explorer (IUE) satellite were outlined by Prof. Robert Wilson of the University College London at a scientific colloquium in May at NASA's Goddard Space Flight Center in Greenbelt, Maryland. At the three-day international meeting 92 papers based on IUE observations were presented.

Prof. Wilson is also European scientific director and manager of the satellite. "What I am most impressed with," he said, "is the breadth of this mission; there is hardly an area of modern astronomy which hasn't been affected." Scientists from 25 countries are participating and some 478 astronomers have been assigned observing time on the satellite. Of these, 63 are from outside the United States, the United Kingdom, and western Europe.

Twelve groups of these scientists, for example, collaborated in the study of X-ray binaries. These are stars which are orbited by a very small, compact object such as a white dwarf, neutron star, or black hole. Material flowing into the compact object's strong gravitational field is heated to high temperatures and emits X-rays.

"One of the truly tantalizing ideas that is emerging from this satellite's observations of hot and cold stars is that magnetic fields and rotation together have much to do with creating the unexpected hot gas we are seeing around stars," reported Dr. Anne Underhill, Goddard Senior Scientist.

Astronomers using data from the IUE are also continuing to study the "halo" surrounding our Milky Way Galaxy which was discovered during early observations by this satellite (see "A Galactic Corona," AstroNews, September 1979). This halo material is hot (about 100,000 degrees Celsius), extends to a distance of 50,000 light-years beyond the Galaxy, and contains oxygen, sulfur, iron, silicon, and carbon.

Other investigators found data contributing to the evidence (discovered by ground-based astronomers) that "twin" quasars lying close to each other in the sky actually were two images of the same object. The light waves reaching Earth have apparently been bent around an intervening, massive elliptical galaxy acting as a gravitational lens, in a fashion predicted by Einstein's general theory of relativity.

Launched on Jan. 26, 1978, the 1700-kilogram (3740-pound) spacecraft is in a synchronous orbit, which enables it to be in continuous contact with either the American or European ground station controlling its operation. Astronomers come to one of these ground stations, located at Goddard and in Vilspa, Spain, to use the spacecraft much like a ground-based telescope. However, they observe the universe in ultraviolet rather than visible light or radio waves.

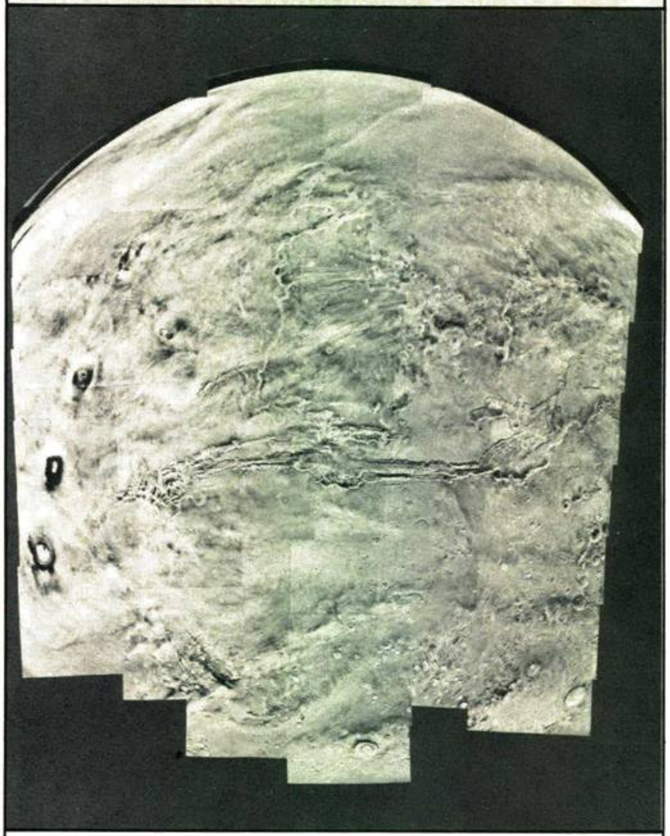
Visible light was the only means of studying celestial objects for most of history, but it is only one of many types of electromagnetic radiation that can now be observed. Other types include radio waves as well as infrared, X-ray, gamma and ultraviolet rays. Except for visible light and radio waves, most of these wavelength ranges are blocked by the Earth's atmosphere and hence must be studied with spacecraft which fly above this atmosphere. Once in orbit, such spacecraft have a unhindered view of the universe and are also not subject to the "clouding out" of visible light telescopes on Earth.

This mission has unique features which enhance its usefulness to science. The astronomer is personally involved with the operation and interacts directly with the satellite. The quality of the data can be assessed immediately and the observation repeated if necessary. The flexibility allows "targets of opportunity," such as comets, novae, and supernovae, to be observed quickly.

The satellite's design lifetime is three years, but the project staff expects it to last much longer. IUE is a joint project of the United States, the United Kingdom, and the European Space Agency.

Requests from the international astronomical community for observing time are much greater than the time available and the satellite is expected to make major contributions to all the areas of modern astronomy.

Unusual Weather on Mars



Rare martian meteorological phenomena have been found in pictures of Mars taken by the Viking Orbiter 1 spacecraft on an exceptionally clear martian day, Feb. 22, 1980.

Several prominent martian features and at least two meterological anomalies are visible in this mosaic of 102 frames, probably the best wide-area view of the martian surface yet obtained. Valles Marineris, as long as the North American continent from coast to coast, stretches across the center. The three huge volcanos of the Tharsis Ridge are at left; from north (up) to south they are Ascraeus Mons, Pavonis Mons, and Arsia Mons.

The most remarkable weather activity in the mosaic appears as a sharp, dark line which curves north and east of the volcano Arsia Mons. Scientists believe this line is either a weather front or atmospheric shock wave. Nothing like this weather phenomenon has ever been seen before on Mars.

The second unusual weather activity consists of four small clouds that hover just north of the crater Lowell, seen at center left in the southernmost frame. Though two of the clouds are so close together as to be almost inseparable even in high enlargement, four clearly separate cloud shadows are cast on the planet surface. The largest cloud is about 32 kilometers (20 miles) in length. Judging from the distance between the clouds and shadows, the clouds float at an altitude of nearly 28 kilometers (91,000 feet). The shadows, which are cast to the south of the clouds, indicate that the photographs near the center of the mosaic were taken close to noon, local martian time. Such distinct cloud pattern shadows are rarely apparent on the face of Mars.

Viking Orbiter 1, which entered Mars orbit June 19, 1976, is nearing the end of four years of planetary operations. The orbiter has used nearly all the attitude-control gas that keeps its solar panels pointed to the Sun and its antenna aimed at Earth. When the gas is exhausted, controllers at the Jet Propulsion Laboratory in Pasadena, California, will send radio commands to the spacecraft, ordering it to cease operating and thus end its long and productive mission. Viking Lander 1, on the surface of Mars, is programmed to operate unattended through 1990, perhaps to be extended to 1994. Viking Lander 1 touched down on July 20, 1976, with a 90-day mission expectation. The Viking Lander 2 and Orbiter 2 have both been shut down. NASA/JPL photograph.

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A Planetary Society

A national organization designed to focus the growing public interest in planetary exploration and the search for extraterrestrial life has been formed by Carl Sagan of Cornell University and Bruce Murray, Director of the Jet Propulsion Laboratory in Pasadena, California. Sagan will serve as President and Murray as Vice-President of the organization, named The Planetary Society.

In a joint statement, Sagan and Murray said: "We are deeply concerned that the pace of solar system exploration has become unduly slow. In the past decade and a half, the human species has performed a preliminary reconnaissance of all the planets known to the ancients. Spacecraft have landed on Venus and Mars; men and vehicles have traversed the lunar surface; Mercury has been flown by repeatedly; and reconnaissance craft have explored the Jupiter and Saturn systems.

"But we are now in danger of seeing the enterprise of planetary exploration stopped because of the lack of a national commitment. The United States will not launch another planetary mission until at least 1984, after an inactive period of six years. The resultant gap of at least 55 months with no U.S. planetary encounters is the longest by far since the beginning of the space age.

"This is particularly ironic because it follows the spectacularly successful Viking, Voyager, and Pioneer missions and occurs at a time of burgeoning popularity of space exploration themes in the media. From observation of this popularity and from our personal experiences, we believe there is an enormous untapped reservoir of support for planetary exploration. The Planetary Society intends to provide the focus for that interest."

The Society will gather a popular constituency for future space exploration, including comet rendezvous, solar sailing, Venus radar mapping, returning planetary soil samples, robot rovers on the terrestrial planets and Jupiter's moons, probes beyond our solar system, and the search for galactic civilizations.

Membership in the Society is open to all. Members will receive a regular bulletin, *The Planetary Report*, as well as pictures and invitations to lectures and exhibits on planetary exploration. The society is incorporated as a non-profit, tax-exempt organization in the State of California. Its business address is:

The Planetary Society
1440 New York Drive
Altadena, CA 91001

Slow-Spinning Sun

The spinning ice skater with arms extended will spin faster and faster as he draws in his arms. This is a common illustration of the phenomenon known to physicists as conservation of angular momentum. The total amount of spin present in any closed system can be redistributed among its parts, but the total must remain the same. Therefore when the skater draws in his arms, reducing the amount of matter spinning at a large radius, his body must spin faster to make up for the loss.

The same rule applies to large systems such as the solar system, where most of the angular momentum present resides in the planets orbiting the Sun (and most of that in Jupiter, the most massive planet by far). The Sun itself, on the other hand, spins relatively slowly, with an average period of about 25 days (different latitudes on the solar surface rotate at different speeds).

But what of other stars? Myron Smith of the University of Texas has recently observed 17 sunlike stars at the McDonald Observatory, and found that these G-type stars all rotate faster than the Sun — with only one exception. The average period observed was 10 days.

Why do other solar-type stars rotate so much more quickly than our Sun? The answer may be simply that these stars lack planetary systems — or at least planetary systems with significant mass — which could carry much of the angular momentum originally present in their formation.

If Smith's rather limited results are borne out by more extensive studies, the conclusion may be that the formation of an extensive planetary system might not be quite the inevitable consequence of stellar formation that many would like to think it is — and therefore that life is a lot rarer in the universe than it would be if all stars had planets.

Sagan's *Cosmos*

A spectacular thirteen-part television series devoted to astronomy and space exploration in the broadest human context will premiere this fall on the Public Broadcasting Service (PBS). The series, *Cosmos,* features Carl Sagan, the distinguished space scientist, ASTRONOMY author, and Pulitzer Prize Winner as host and principal writer. In *Cosmos*, Sagan will guide television audiences on a spectacular voyage through space and time to explore what he calls "the deepest connections of human beings with a vast and awesome universe in which we float like a grain of sand in the cosmic ocean."

Cosmos was filmed and videotaped during more than sixteen months at more than forty locations around the world and at several special effects studios in Hollywood.

The episodes will probe spacecraft missions of discovery to the planets, black holes, the origin of matter, the human brain, alternate universes, time travel, communication among the whales, the death of the Sun, and the search for life on other worlds.

The series will investigate a wide range of questions, including Hindu cosmology, cosmic catastrophes, martian canals, robots, travel to the stars, cosmic influences on the evolution of life, historic voyages of exploration, the deciphering of Egyptian hieroglyphics, the origin of life, contact with other civilizations in space, the birth and death of stars and galaxies, the future of the Earth, and questions concerning the origin and fate of the universe.

Aboard a specially-designed "spaceship of the imagination," Sagan will take television viewers on a ten-billion light-year journey from the far reaches of the universe to the Earth.

Sagan's spaceship will hurtle past exploding galaxies and stellar nurseries, the Pleiades star cluster, pulsars, lightning storms on Jupiter, the rings of Saturn, the broiling surface of Venus, and a distant solar system destroyed when its star becomes a supernova. The spaceship will travel to the surface of Mars, skirting the great Olympus Mons volcano and racing down the canyons of Vallis Marineris. The special effects that audiences will see through the spaceship window have been achieved with the utmost scientific accuracy, and incorporate specially commissioned astronomical art executed by a number of well-known space artists, many of whose works have appeared in ASTRONOMY.

"The Cosmic Calendar," a special effect in which the fifteen billion years since the Big Bang beginning of the universe will be depicted as compressed into a single cosmic year, is another integral part of *Cosmos*.

In one of many journeys back into time, *Cosmos* will recreate the million-volume library and research institute of ancient Alexandria, birthplace of many of the sciences explored in the series.

Sagan received the Pulitzer Prize for non-fiction for his book "The Dragons of Eden," and has also written for ASTRONOMY magazine. He is Director of the Laboratory for Planetary Studies and the David Duncan Professor of Astronomy and Space Sciences at Cornell University, Ithaca, New York, where he also serves as associate director of the Center for Radiophysics and Space Research. He has played a leading role in the Mariner, Viking, and Voyager expeditions to the planets, and has extensive experience in the presentation of science on television.

A joint production of Carl Sagan Productions, Inc. and KCET, Los Angeles, *Cosmos* will premiere at 8 p.m., EDT, on Sunday, September 28, on the PBS network.

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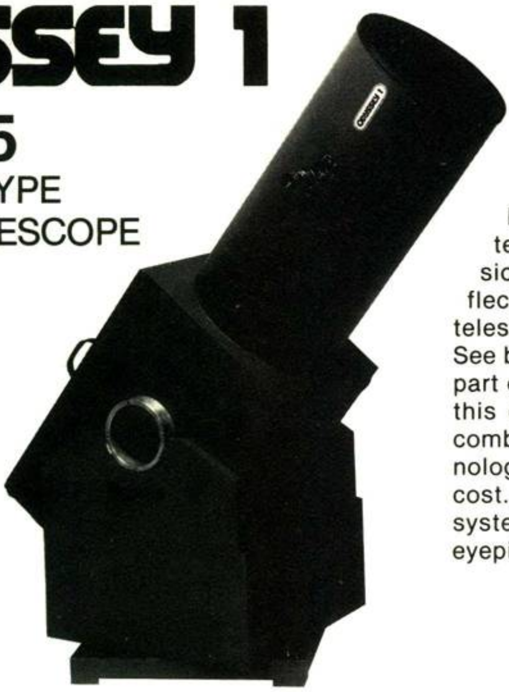

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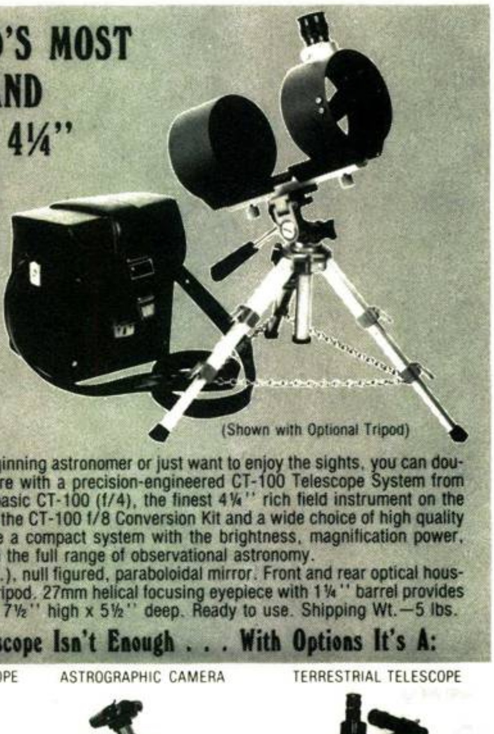

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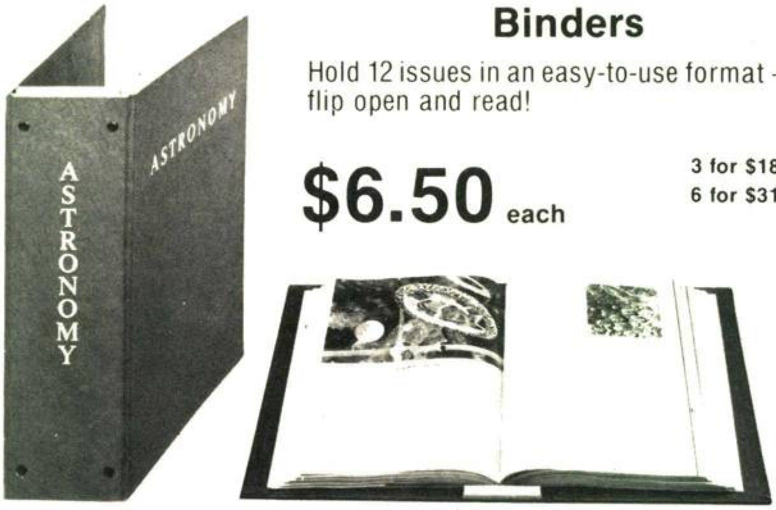

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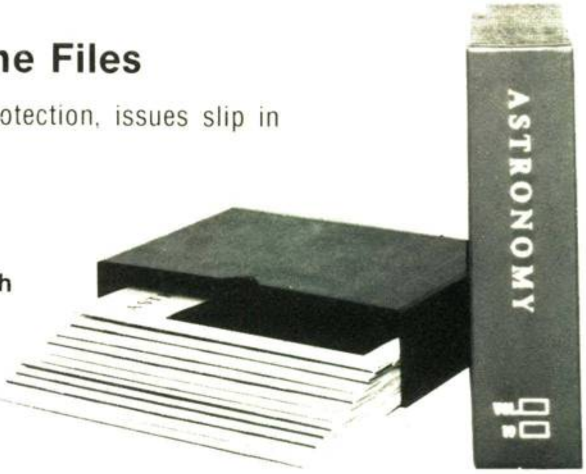

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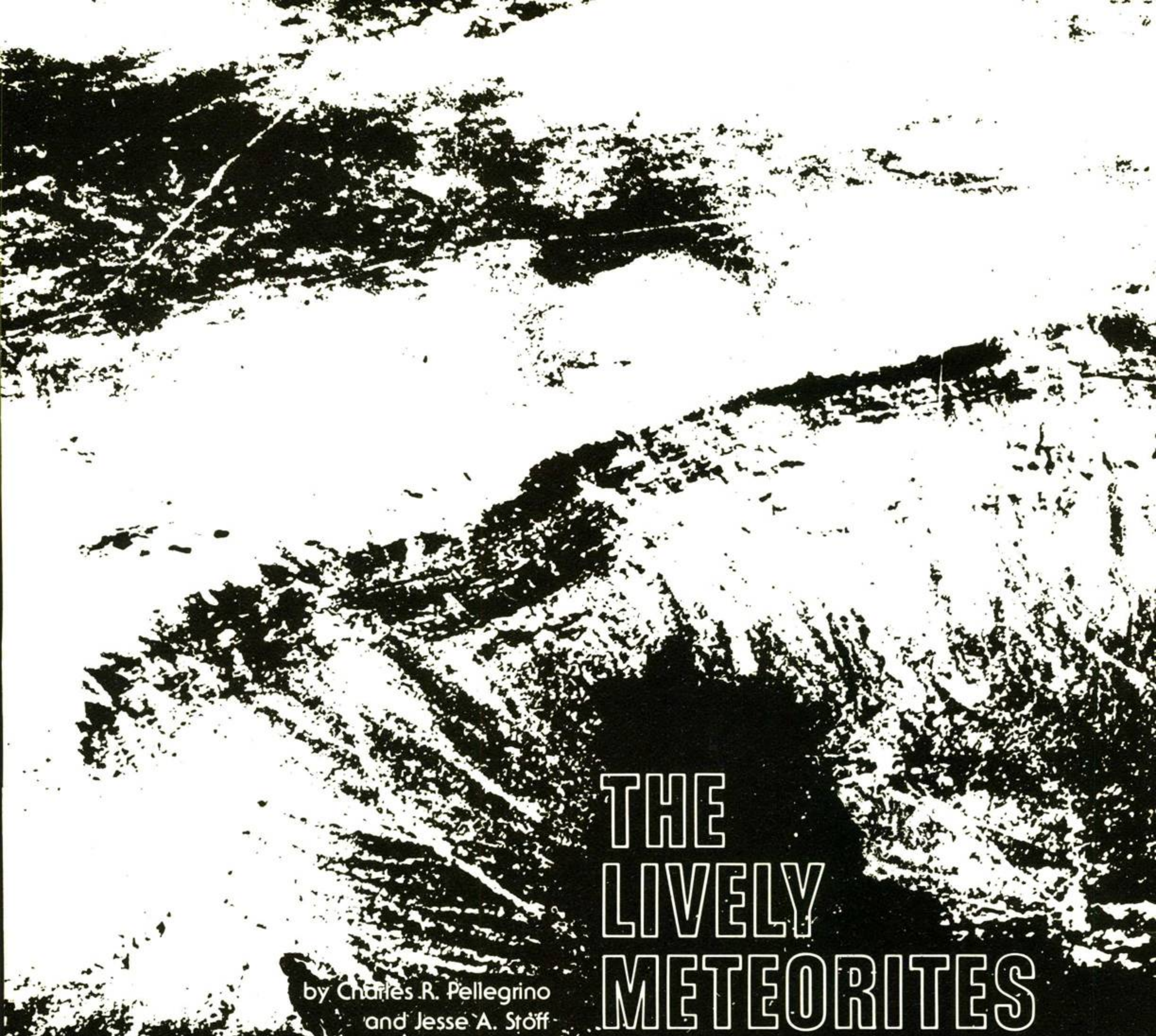


THE LIVELY METEORITES

by Charles R. Pellegrino
and Jesse A. Stoff

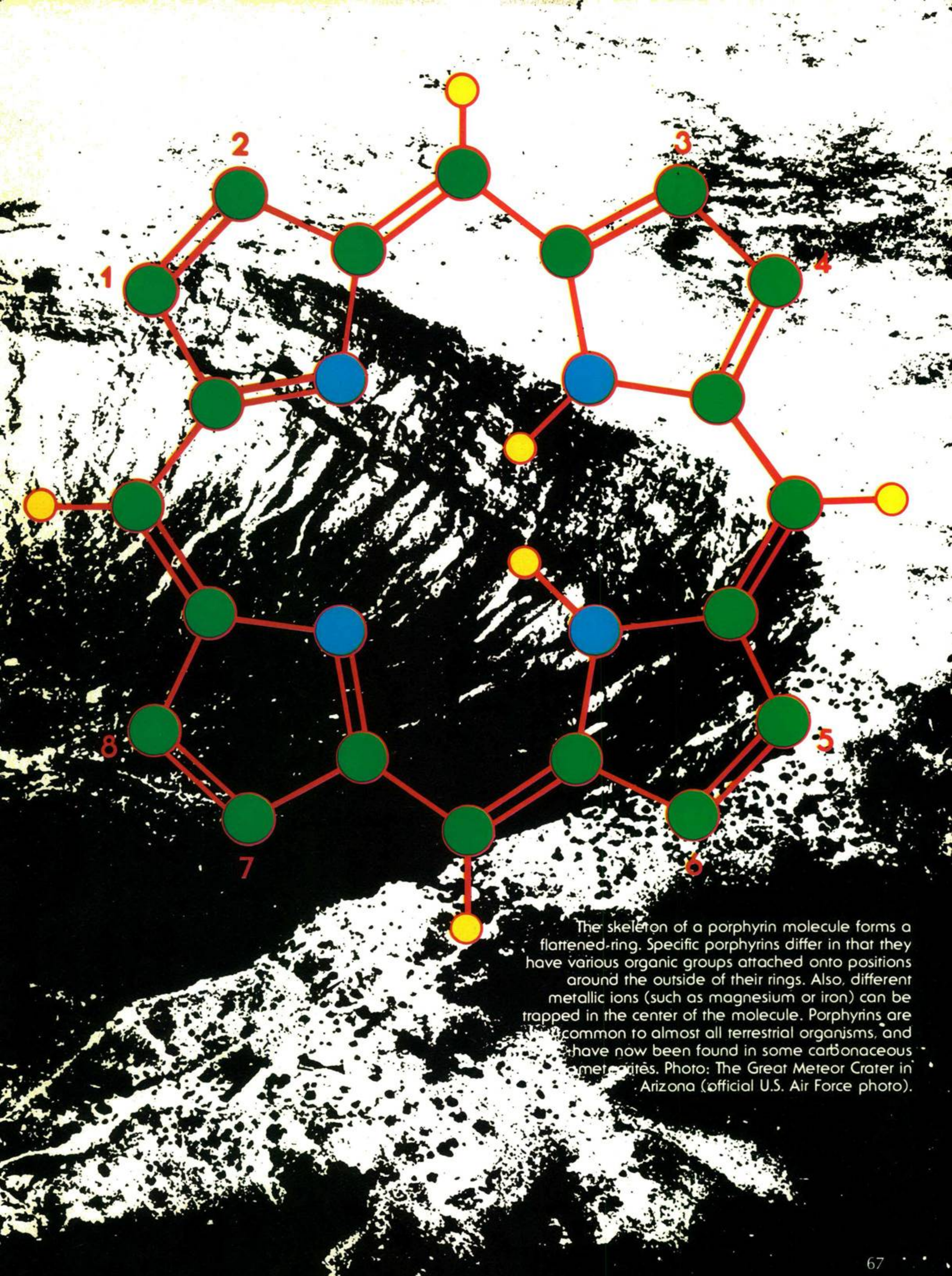
Pouring out of every young star is an unquenchable torrent of raw energy. Most of that energy is lost — wasted — destined never to come into contact with matter anywhere in the vast unfillable void of outer space. But there are obstructions: a pebble here...a hydrogen atom there...a planet...an atmosphere. And where energy does splash up against matter, it must invariably cause changes in it.

Within several thousand kilometers of these infant suns the sheer pressure of the energetic photons of light is strong enough to propel you away. Suppose that nearby a strange, airless world orbits. Even at a distance of 40 million miles (60 million km), its surface is powdery, pounded, and dry, its sky dominated by a broad white sun. Such a planet would be baked by an unrelenting shower of heat and light. Gases, if they were present at all, would blaze instantly and stream away into space. The heaviest as well as the lightest of metals would quickly soften, bubble, and boil. Here the elements seem condemned to disorder by the celestial din of a nearby star.

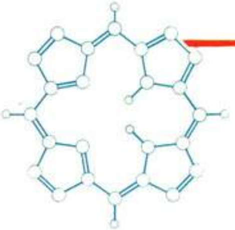
Farther away — much farther — the radiant energy has dissipated, spread out over so much emptiness. The surfaces of wandering, stony objects are lit only faintly in this place where the roiling sun is little more than a distant bright star. The steady trickle of energy is too feeble to animate the elements. Carbon dioxide, methane, water (things once vaporous) have condensed out here, solidified and accumulated — crystalline, unchanging.

Somewhere between these two regions is a boundary area where matter is neither fried nor frozen, but heated to just the right temperature. Such a regime is found around every singular star, although the boundaries will advance and retreat as the stellar energy output fluctuates. If a planet orbits within this zone, and if it possesses sufficient mass to support the right kind of atmosphere, then sooner or later, carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur will emerge from their prolonged exile in disorder and bind themselves together, forming structures of ever-increasing complexity.

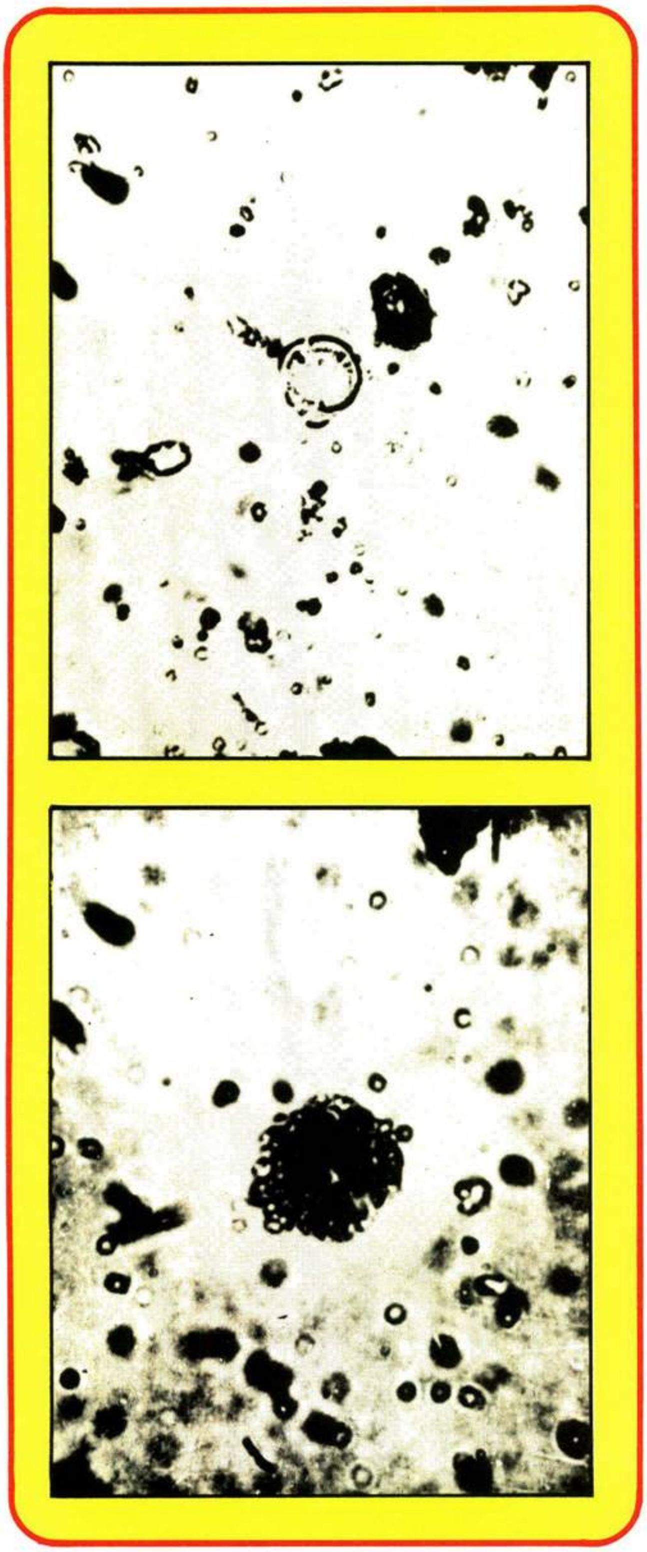
The rest is clear going. Impelled by a steady flow of radiant energy, the once inanimate elements are transformed into a symphony of molecular architecture, always in motion, always changing, segregating in solution, and evolving cycles for the storage and release of energy. Finally, some kind of metabolism makes its appearance: not yet *life*, but very close to it.



The skeleton of a porphyrin molecule forms a flattened-ring. Specific porphyrins differ in that they have various organic groups attached onto positions around the outside of their rings. Also, different metallic ions (such as magnesium or iron) can be trapped in the center of the molecule. Porphyrins are common to almost all terrestrial organisms, and have now been found in some carbonaceous meteorites. Photo: The Great Meteor Crater in Arizona (official U.S. Air Force photo).



The spheroidal class 1 "organized elements" pictured below were recovered from crushed preparations of the Mokoia meteorite. Such formations bear a striking resemblance to organic life forms. Photos courtesy of NASA, Caltech, and the Jet Propulsion Laboratory.



Organic Matter from Space

Only recently has our species developed the ability to leap off the Earth and steal fleeting glimpses of other worlds. We are children with strange new senses — probing, touching, tasting, turning over rocks and poking our fingers underneath. That life can evolve on a planet like Earth is obvious. But the possibility of its occurrence elsewhere, outside Earth, has tugged at man's imagination for innumerable years.

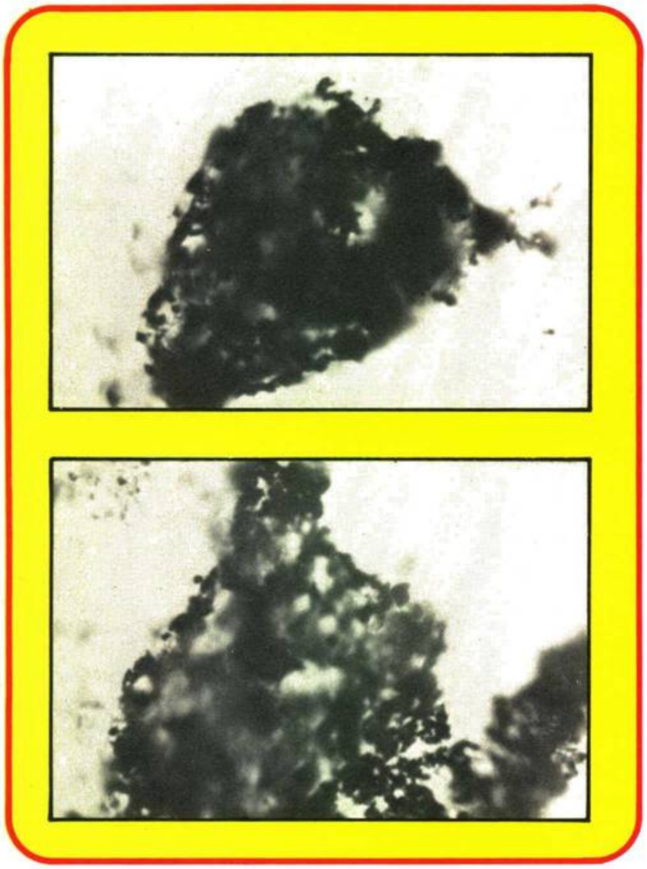
On the Moon and inner planets we have found dust in great abundance, but no allergens. The Viking missions revealed Mars as a planet probably untouched by life. The organic content of its soil, over a broad range of molecules from one or two carbon compounds to naphthalene (better known as "moth balls"), is generally below some parts per billion.

The Viking Landers arrived. Their mechanisms ingested the dust and air. Organic molecules, supplied by the experiments from Earth, were immediately assailed and dismembered by corrosive superoxides (Fe_2O_3) in the soil. It is now apparent that powerful oxidizing agents, formed by ultraviolet decomposition of the carbon dioxide atmosphere, have rendered the martian wilderness sterile and lifeless.

Ironically, the quest for earthlike biochemistry may soon focus not on Mars, but on its tiny inner satellite Phobos. According to measurements made by the Viking Orbiter-1 spacecraft, Phobos (whose spectral signature coincides almost exactly with the asteroids Ceres and Pallas) is similar in composition to Type I carbonaceous chondrite meteorites. An appreciable number of these meterorites contain as much as six to eight percent carbon (the most abundant element in this part of the universe after hydrogen, helium, and oxygen). The carbon matrix of the Type I carbonaceous chondrites is literally laced with organic molecules, including fatty acids, amino acids, alcohols, sugars, purines, and pyrimidines.

Perhaps the most striking examples of molecular ornamentation thus far identified in meteorites are porphyrins, first discovered in 1964 in samples of the Orgueil meteorite which fell in France in 1864. The porphyrins (or closely related compounds) are common to almost all terrestrial organisms. The inclusion of iron or other metals in their centers allows them to function ideally as electron transfer catalysts. In animals they have become the foundations for oxygen-carrying blood pigments. The magnesium porphyrin, because of its tendency to act as an "electron race track" when struck by energy from the Sun, was incorporated into living cells as an energy storage molecule. Retained, it ultimately evolved into chlorophyll, the energy-capturing molecule that sustains widespread life on this planet.

Organic pigments extracted from the Orgueil meteorite appear distinct from those found on Earth, ruling out the possibility of earthly contamination. Chlorins, a group of compounds closely related to the porphyrins, are plant-related pigments that differ from porphyrins in having two "extra" hydrogen atoms added to the basic porphyrin structure. Terrestrial dusts, soils, and recent sediments — the possible contaminants — contain a wealth of chlorins far outnumbering the porphyrins. In carbonaceous chondrites, however, the exact opposite appears to be true; the chlorins are virtually absent. This discovery makes sense only if the Orgueil porphyrins are



These microstructures were found in 3.7 billion-year-old sedimentary rocks from Greenland. The evidence suggests a non-biological synthesis of the structures which possibly represent the immediate precursors of living cells. Photos courtesy of Bartholomew Nagy, Department of Geosciences, University of Arizona.

indigenous to the meteorite, for such anomalies are expected if the origin of these compounds lies in some pre-living chemical process rather than the tissues of terrestrial plants and animals.

Lifecloud

Several researchers have found evidence that suggests the parent body or bodies that give rise to carbonaceous chondrites provided a warm, moist environment with an alkaline pH and slightly reducing conditions, ideal conditions for producing organic molecules. But where could such bodies have existed?

Radiometric methods of dating place the formation of carbonaceous chondrites roughly 4.6 billion years ago, a time when the primordial cloud of gas and dust was evolving rapidly into the Sun, planets, meteorites, and other debris of the solar system. The ingredients of the primordial nebula probably accumulated from the ejecta of exploded stars, ultimately finding their way into such things as the pages on which these words are printed, the staples that bind them, and your hand that holds them.

Recent data even suggest that interstellar grains of unusual isotopic composition, synthesized by the lives and deaths of stars, were stirred into the rock material of carbonaceous chondrites even as they accreted to form the parent bodies. For example, the Murchison meteorite (which fell in Australia in 1969) has yielded an unusual xenon component, believed to have been forged in the interior of a giant red sun. Nuggets of material extracted from the Allende meteorite (Mexico, 1969) exhibit peculiar isotopic ratios which imply the occurrence of a nearby supernova just prior to the onset of condensation and fractionation events within the presolar nebula (see "Cosmic Contamination" in the June 1980 issue of ASTRONOMY). Consequently, the organic molecules of carbonaceous meteorites seem to exist side-by-side with the outgassed fusion products of stars.

How did "biochemistry" come to be associated with the wreckage of stars? If we suppose that the Orgueil porphyrins originated on some primordial planet which has since broken up, then we are also forced to accept a series of very unlikely events whose probability goes down with their multiplication. We must, for example, consider how organic nuggets of preplanetary matter might survive planet formation and the tremendous geological pressure and heating that would follow. Furthermore, a planet with gravity sufficient to hold an atmosphere and water on its surface does not simply break itself apart and go scattering its pieces about the solar system.

These and similar problems suggest that Charles Darwin's "warm little pond" — the pools, tidal flats, and rivers of an earthlike world — is not an invariable and universal requirement for the development of chemical evolution. Recent observations in radio astronomy confirm the presence of an abundance of simple organic molecules in interstellar gas clouds that probably resemble our own solar system at the stage of prestellar collapse. The compounds observed include key steps in chemical evolution, such as hydrogen cyanide (HCN), formaldehyde (H_2CO), and cyanoacetylene ($HC{\equiv}C{-}N$). Conceivably they might have been synthesized by condensation effects within the cooling, outracing shells of expired stars, but the brief period of bonding activity could not possibly have lasted very long. Expansion and rarefication of the ejected matter, accompanied by steadily dropping temperatures, would have demanded that organic synthesis grind to a halt.

Now let's try to imagine the origin of the carbonaceous chondrites. We think the presolar nebula contained the cold, carbon-rich ejecta of at least a handful of dead stars. Initially, any residual carbon compounds must have existed as frozen, inanimate molecules. However, the collapse, aggregation, and packing together of cosmic dust dramatically altered that condition. Even small accumulations of rock, perhaps approximating Phobos in size, would have been heated by relatively short-lived radioactive elements. At their centers, temperatures possibly climbed as high as 2,000° C, as would seem to be indicated by the presence of partially remelted silicates in some carbonaceous chondrites. The mean surface temperature, on the other hand, would have remained generally below 0° C. Somewhere between the cold, airless surface and the molten or nearly molten core, a zone of thickness measured in kilometers existed where the temperatures ranged between the freezing and boiling points of water.

Could this be the source of the warm, stable environment proposed by some planetary scientists? The original heating up of the parent bodies made the emergence of such zones inevitable, of course. Assuming that the right kinds of atoms were present, they certainly

look like potential sites for the thermal synthesis of organic compounds.

Let's look a bit closer at the idea. Some of the basic constituents of carbonaceous chondrites furnish criteria for a hypothetical environment inside the warm, intermediate layers of a parent body. There was water: shown not only by the presence of indigenous water, but also by mineralized structures such as magnetite spherules (Fe_3O_4) and veins of magnesium sulfate ($MgSO_4$) whose formation appears to require the presence of liquid water. The matrix, or groundmass of carbonaceous chondrites, consists largely of very fine particles of silicate minerals, some occurring as stacked micaceous sheets. The total surface area accessible to water and organic compounds percolating through the grains was therefore enormous, providing excellent substrates for the capture and concentration of prebiological molecules. Furthermore, the abundance of negative and positive charges carried by the silicates and associated metals not only could have served to bind charged molecules to the grains but also might have enabled them to act as primitive catalytic centers. In short, the insides of these bodies were wet and suitable for chemical activity.

Non-biological processes are quite capable of generating an enormous number of organic microstructures, as illustrated by these photomicrographs taken after 20 hours of electrical discharge through a mixture of methane and nitrogen over water. In a typical spark discharge experiment, more than 60% of the total carbon present in the methane is transformed into organic microstructures like these. Generally they are hollow, and exhibit complex external and internal forms. The larger objects shown here are approximately 20 microns in diameter. Photos courtesy of Clair E. Folsome, Laboratory for Exobiology, University of Hawaii.

But this, too, was to pass.

The decay of radioactive elements could sustain the warmth for only a short time, perhaps a half billion years or so — a mere fortnight in terms of the solar system. One can easily imagine the intermediate prebiological zone sinking deeper and deeper into the interior of a planetesimal, until finally the glow went out and its depths became frozen. Meanwhile, the planets formed.

The Troublesome Microstructures

How far could chemical evolution have gone? Could life have formed inside the chondritic bodies? Having established on several grounds that the organic compounds contained in carbonaceous meteorites originated outside of the Earth, what remains to be settled is whether they are pre-living organic matter or the actual products of cellular life. Although the evidence weighs heavily in favor of the pre-living hypothesis, the presence of ambiguous microfossils (or pseudofossils) in carbonaceous chondrites does raise questions as to how far molecular evolution might have advanced in the meteorite parent bodies.

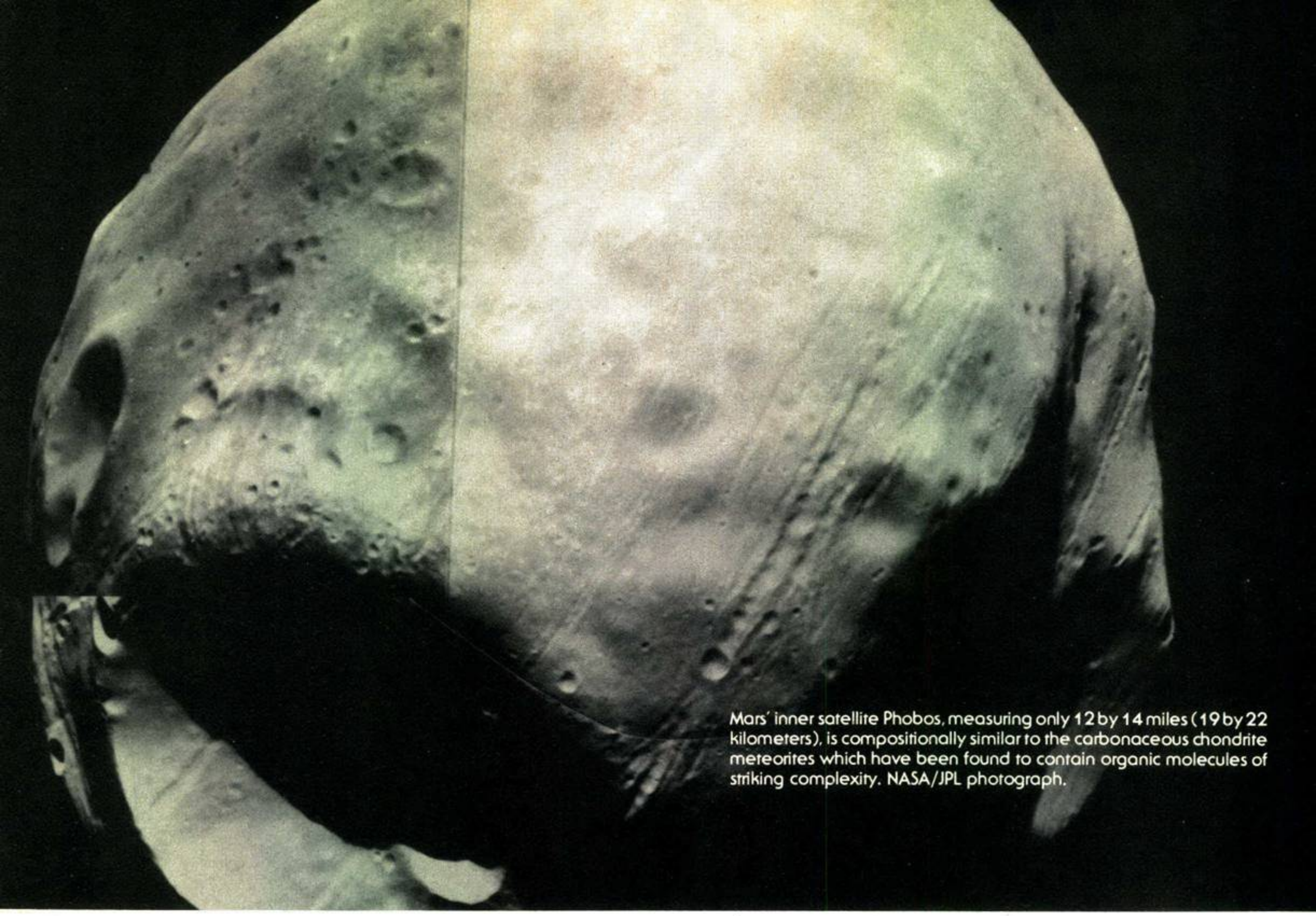
The microstructures, cautiously named "organized elements," range from 5 to 30 microns (10,000 microns = 1 centimeter) in diameter, and fall generally into two classes. Particles of the first class are more numerous and are probably native to the meteorites. But they are rather featureless objects and seem to lack specific properties indicative of once-living microfossils.

The class 2 particles are quite rare. They exhibit highly structured forms, clearly biogenic, but the majority of them show a strong resemblance to pollen grains and other common airborne contaminants! Some of the spiny class 2 elements have even been identified as ragweed pollen by several pollen experts.

In 1963, Dr. Bartholomew Nagy of the University of Arizona and his co-workers sought to determine whether "organized elements" might simply be false alarms, triggered perhaps by artifacts or "jokes of nature," such as mineral spheroids or hexagons that mimic or give the appearance of microfossils. From several meteorites they extracted small, rounded, class 1 objects, and investigated them with an electron microprobe. They found some to be laden with silicates or limonite (hydrated ferric oxide). When the mineral constituents were removed with the aid of acids, the majority of these microstructures dissolved completely out of existence, which supported the proposition that they were natural mineral formations. Nevertheless, a few left residues or bodies that could be seen under a microscope: round, acid-insoluble "shells" that contained no elements heavier than magnesium, indicating that the objects were possibly composed of carbon-based material.

It is thus tempting to suggest that these structures are a residue of life in meteorites that became impregnated with minerals, "fossilized" in much the same way as terrestrial microfossils are formed. They closely resemble the oldest protocell-like objects known on Earth (approximately 3.7 billion years old, excavated from the Isua micaceous metaquartzite deposits of Greenland), and are identical to organic microstructures produced on water surfaces during spark discharge experiments.

In still another experiment, spheroidal microstructures separated from the Mokoia meteorite (date of fall: 1908,



Mars' inner satellite Phobos, measuring only 12 by 14 miles (19 by 22 kilometers), is compositionally similar to the carbonaceous chondrite meteorites which have been found to contain organic molecules of striking complexity. NASA/JPL photograph.

New Zealand) were shown to take up various biological stains. During control experiments in which meteorite fragments were heated overnight at 700° C and the stain test repeated, absorption did not occur. This result would be expected if the meteorite contained organic particles, since they would be destroyed by the high temperature.

Although this might appear to have a bearing on the interpretation of lifelike signatures in meteorites, two important points must be evaluated: first, spheroids are a natural equilibrium form in nature, and second, the results described here would be reproduced exactly if the class 1 "organized elements" were in fact nothing more glamorous than organic compounds adsorbed onto mineral grains.

Presently, researchers are of the general opinion that some of the Mokoia microstructures are mineral grains, while others are associations of sulfur droplets and hydrocarbons, presumably of non-cellular origin.

In view of recent theories of chemical evolution, it would be most surprising not to find complex organic particles or protocells existing coincidentally with amino acids, porphyrins, and other carbon compounds in carbonaceous meteorites. Small organic molecules, such as amino acids, are synthesized easily in the laboratory by subjecting mixtures of primeval gases (typically methane and ammonia) to electrical discharges over water. Invariably, highly polymeric material is also produced — appearing during the first 24 hours as an accumulation of dark matter on the glass walls of the reaction vessel, and as a thin oily film on the water's surface. If the water is agitated or made to splash against the walls of the flask, the polymers separate from the surface to form organic microstructures ranging in size from 1 to 40 microns. Usually they are spheroidal bodies with textured surfaces and clearly structured interiors, but molecular biologists have described a remarkable variety of form and structure, including delicate tube-shaped objects with hollow interiors and occasional hints of septa.

Virtually the entire gamut of "organized elements" observed in meteorites and terrestrial Precambrian rocks, is represented in the products of spark discharge experiments. Similar particles were probably present in our own seas as well as in the warm layers of the meteorite parent bodies from the very moment that simple organic molecules came into being. With hollow interiors and membranes acting as barriers against the outside world, each protocell carried within itself the potential for isolating chemical reactions and evolving low-level metabolic abilities. They were not life, but they were getting close to it.

The significant thing is that precursor organic particles, from which life forms could have later evolved, are apparently embedded in carbonaceous chondrites. If such an organization of matter can be duplicated in two places in the same solar system, then the union of carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur is seemingly not an unusual occurrence. Consequently, as we continue to look outward from the Earth, we shall very likely find this part of the universe literally smeared with biochemistry, and perhaps more....

Charles R. Pellegrino is currently completing his fourth year of medical studies at the New York Medical College. He has engaged in research in the areas of cardiovascular physiology and evolutionary biochemistry. Jesse A. Stoff, currently on the faculty of Victoria University in Wellington, New Zealand, is finishing a Ph.D. in marine biology, with particular emphasis on evolutionary biochemistry. They are collaborating on a book on meteorites and evolutionary biochemistry.

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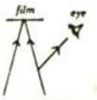

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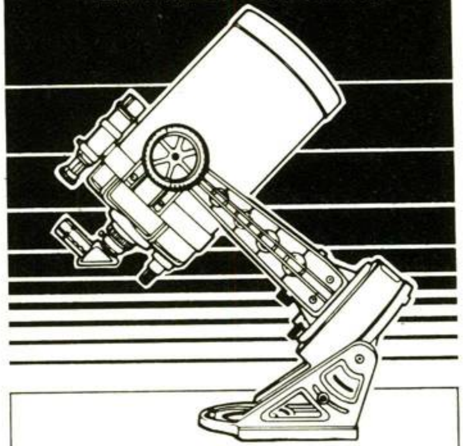

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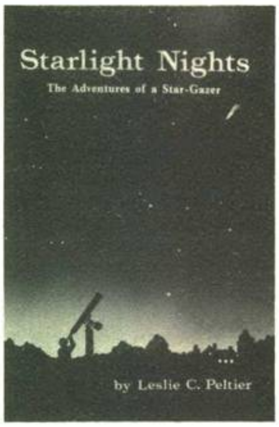

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ANNOUNCEMENT — Visual Photometry Opportunities for Minor Planets in 1980 is free for a SASE with 28¢ postage. This paper gives predictions for observing asteroids in AAVSO fields. Write to Planetary Astronomy Magazine, P.O. Box 15854, Baton Rouge, LA 70895.

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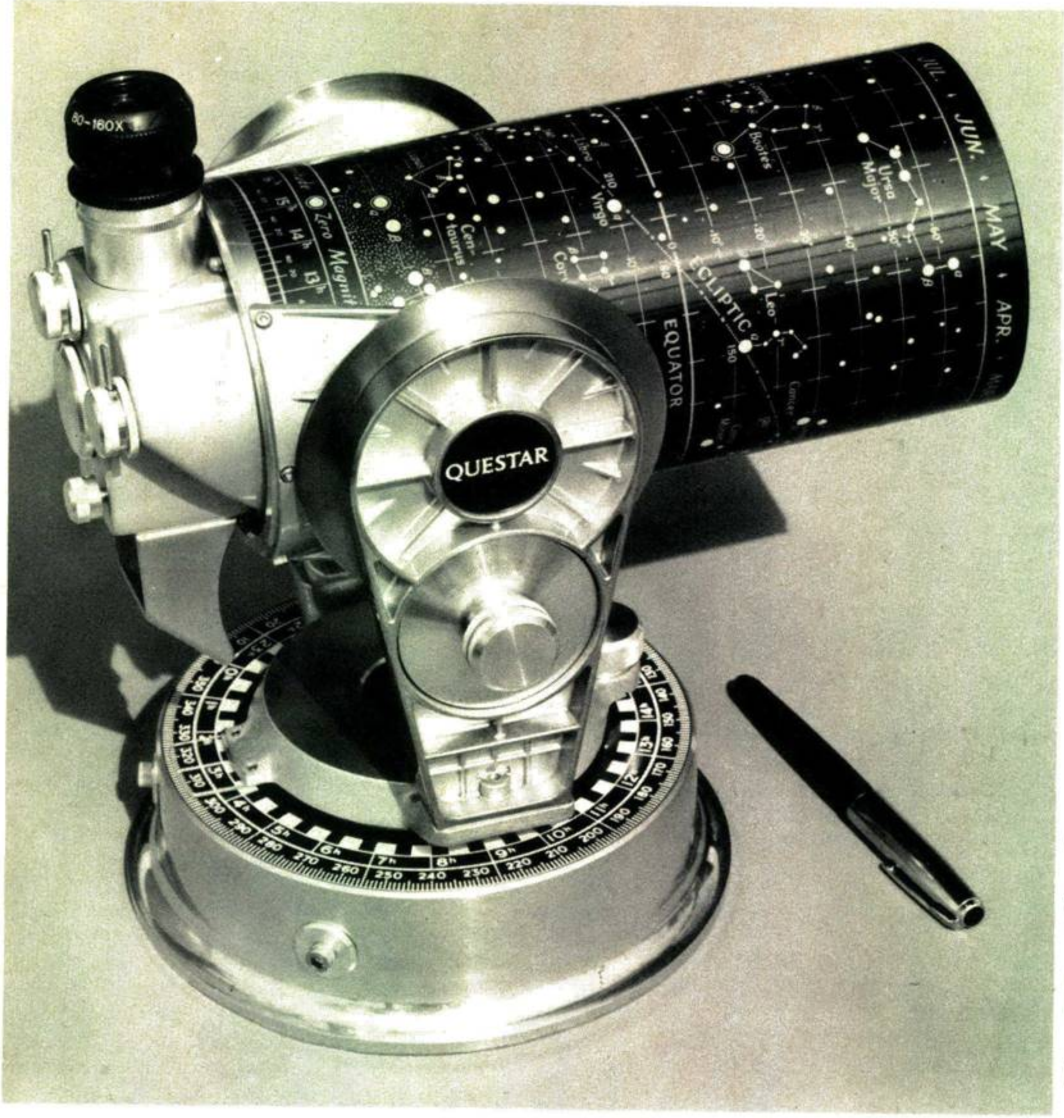

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close-up on capricornus

through the eyepiece

The "planet show" this month won't be very spectacular, since the two best attractions — Jupiter and Saturn — are out of sight behind the Sun, and another favorite, Mercury, is also hard to locate. But things will improve in a month or two, so don't give up the scope!

Mercury

Mercury passed superior conjunction on the 26th of last month and now moves into the evening sky — at least technically. But you still won't see it unless you try during daytime hours because its elevation is very low. Greatest eastern elongation comes on October 10th, but even then Mercury will be just about on the horizon by the time the sky darkens enough to see it, some 45 minutes after sunset.

Venus

Venus reaches maximum elevation over the eastern horizon during the period from September 11th to 16th — a height of 33°, 45 minutes before sunrise. Its brightness then will be -3.8 magnitude. Through a telescope, Venus' 19.7 second-of-arc ball will appear gibbous (60% illuminated).

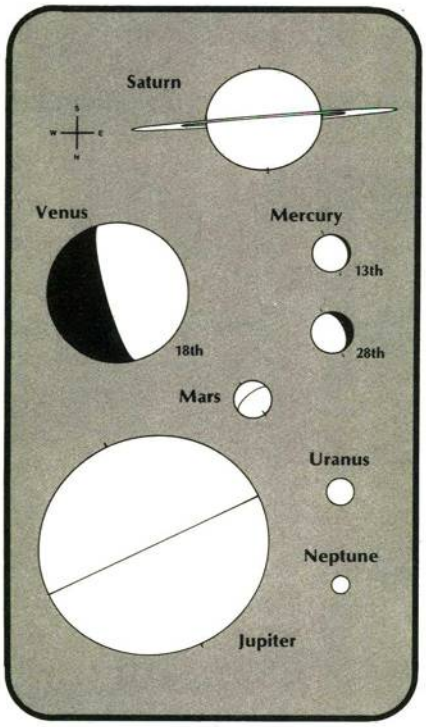
During this same period (on the 14th and 15th), Venus will be passing just 3° south of the Beehive Cluster, M-44. Lenses of 500 mm or less focal length will accommodate both the cluster and Venus on the same 35 mm frame. This is known as a subtle hint, photographers! (See also Vesta in the Asteroids section.)

Venus rarely offers any details to the onlooker, but you will be able to follow its slow progress away from us: its apparent size will diminish and the disk will gradually round out over the coming months to nearly "full."

Refractors can certainly give fine images as Joszef Habina's Moon photo shows. Seen near first quarter, Mare Serenitatis lies on the terminator at lower center. Habina, a resident of Budapest, Hungary, used a 6" f/15, exposing Orwo UT18 slide film for a half second. This shot wins September's "Best Astro-Photo" award.

Earth

The ol' home planet reaches heliocentric longitude 0° at 21:09 UT on September 22nd. This marks the moment when the Sun crosses the celestial equator southbound and autumn commences for Earth's northern hemisphere. At this time we are 1.00331+ astronomical units from Sol, a distance that'll keep on dwindling until perihelion comes on January 2, 1981.



Moon

A daylight occultation of Aldebaran on September 1st will be visible west of the Rockies, but the event takes place with the Moon so low that only the disappearance (at 19:00 to 19:20 UT, depending on where you are) can be seen from most places. The disappearance comes on the bright limb of the 22-day-old Moon, and will be hard to observe. Use moderately high powers (once you've located the Moon and star) coupled with a red filter.

Mars

Still hanging in there, dim little Mars continues its race away from the oncoming Sun. Setting 2 hours after the Sun on the first of September, by month's end the Sun will have gained only 15 minutes on it.

Realistically, you aren't going to see much of it in a telescope. Its disk is scarcely 4.5" to 5" in diameter, and because Mars lies so low, you'll be looking at it through a lot of turbulent atmosphere.

Asteroids

1 Ceres lies at $6^h58^m09^s$, +23° 15′ 53″ (1950 coordinates) on the 15th of September. This places the magnitude 7.7 object in central Gemini, a region rising a couple of hours before the Sun.

2 Pallas can be found on the 15th at $2^h41^m23^s$, -10° 09′ 54″ (1950). Since this area on the Cetus-Eridanus border rises around 11 p.m. local daylight time, you shouldn't have much difficulty locating the 8th magnitude asteroid.

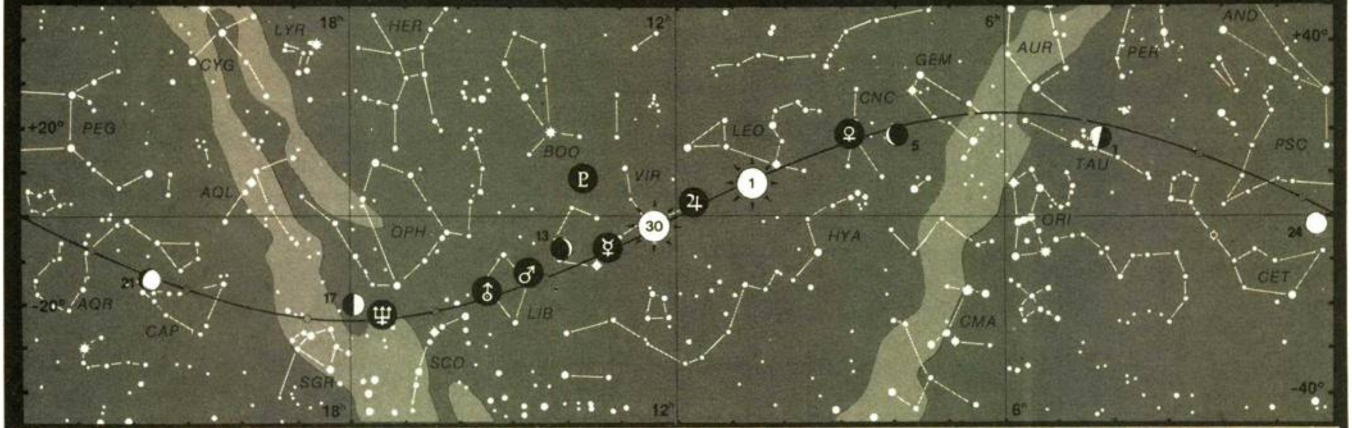
3 Juno is in conjunction with the Sun on the 17th of September — forget about it this month.

4 Vesta, at $8^h45^m39^s$, +18° 59′ 07″ (1950) on the 15th, lies in central Cancer, just to the east of M-44, the Beehive Cluster. Rising about 3 hours before the Sun, the asteroid won't be hard to find.

In addition, from September 9th to 11th, it'll be skirting the southern edge of the cluster and providing excellent opportunities for photographs showing daily motion. On the 18th, Venus will pass by about 3° to the south, another photo-opportunity.

6 Hebe, a 9.3 magnitude object, can

planetary data for september 1980


LYR
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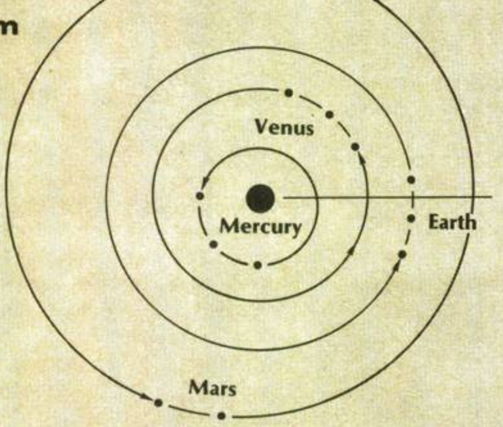
inner solar system


Venus
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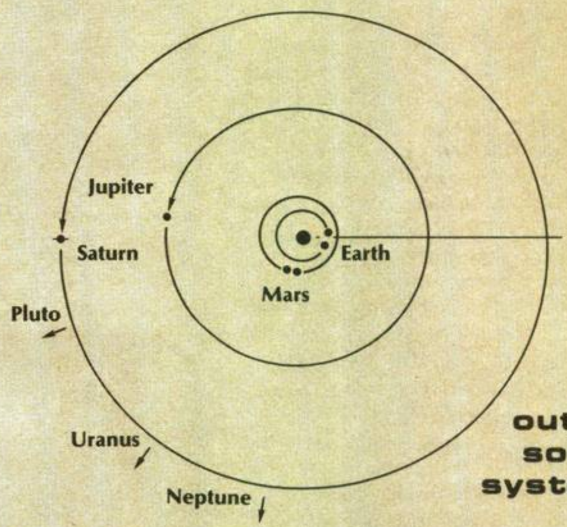

Jupiter
Saturn
Earth
Mars
Pluto
Uranus
Neptune

outer solar system

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (1980.8)	Dec.
Sun		10	--	31.8′	--	1.01	--	--	167°26.5′	$11^h13.8^m$	4°57.9′
		20	--	31.9′	--	1.00	--	--	177°11.5′	$11^h49.7^m$	1°07.2′
Mercury	☿	10	–0.5	4.9″	93%	1.36	0.43	210°05.9′	178°21.5′	$12^h00.6^m$	0°41.5′
		20	–0.1	5.2″	86%	1.28	0.46	239°47.3′	195°18.7′	$12^h57.3^m$	–6°40.9′
		30	0.0	5.7″	78%	1.17	0.46	267°22.8′	209°26.8′	$13^h48.8^m$	–13°05.7′
Venus	♀	10	–3.8	20.2″	58%	0.83	0.72	41°57.1′	121°59.1′	$8^h16.9^m$	17°59.9′
		30	–3.7	18.5″	62%	0.91	0.72	57°59.4′	143°56.4′	$9^h01.5^m$	16°02.6′
Mars	♂	15	+1.5	4.8″	93%	1.95	1.49	251°03.3′	220°41.5′	$14^h33.9^m$	–15°39.8′
Jupiter	♃	15	–1.2	28.6″	100%	6.43	5.43	170°27.6′	170°40.9′	$11^h28.9^m$	4°29.1′
Saturn	♄	15	+1.2	14.2″	100%	10.49	9.50	179°30.7′	178°47.0′	$12^h00.3^m$	2°12.6′
Uranus	⛢	15	6.1	3.6″	--	19.25	18.77	234°39.2′	232°07.5′	$15^h20.3^m$	–18°08.3′
Neptune	♆	15	7.9	2.4″	--	30.30	30.28	261°26.2′	259°38.4′	$17^h16.7^m$	–21°42.8′
Pluto	♇	15	14.0	--	--	30.95	30.11	201°04.1′	200°10.0′	$13^h39.3^m$	7°33.3′

moon data

Last quarter .... September 1 at 18:08
New moon .... September 9 at 10:00
First quarter .... September 17 at 13:54
Full moon .... September 24 at 12:08
Last quarter........... October 1 at 03:18

Apogee: September 12 at 9^h .. 406,237 km
Perigee: September 25 at 3^h ... 357,439 km

universal time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times in Through the Eyepiece are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska and Hawaii, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then the time in EDT would be 11 p.m. June 6. Likewise, 03:00 UT on Sept. 2 becomes, in PDT, 8 p.m. on Sept. 1.

be found on the 18th in north central Eridanus at 1950 coordinates $3^h 58^m 50^s$, -1° 21′ 36″. The region rises around 1 a.m. local daylight time.

Jupiter and Saturn

Both planets arrive at conjunction with the Sun just 10 days apart: Jupiter at 10^h UT on the 13th and Saturn at 2^h UT on the 23rd. From an observational point of view, this puts both planets out of action for the month of September, though if you look carefully, you may catch sight of Jupiter very low in the east during the last day or two of September (3° high in azimuth 88° on the 30th).

Uranus

Over 19¼ astronomical units away, the 3.6 second-of-arc disk of Uranus will show little more than a tiny, non-stellar image in your eyepiece. Locate it by aiming your scope at Gamma (γ) Librae. Then sweep southward about 2° and westward ½°; you'll spy three 6th magnitude stars in a flat triangle. Magnitude 5.6 Uranus is 1½° south and 2° west of the westernmost of the three stars.

On the night of the 11th to 12th, it'll pass about 1 minute of arc north of the 6.2 magnitude star 28 Librae. This is a class G8 star about 450 light-years distant.

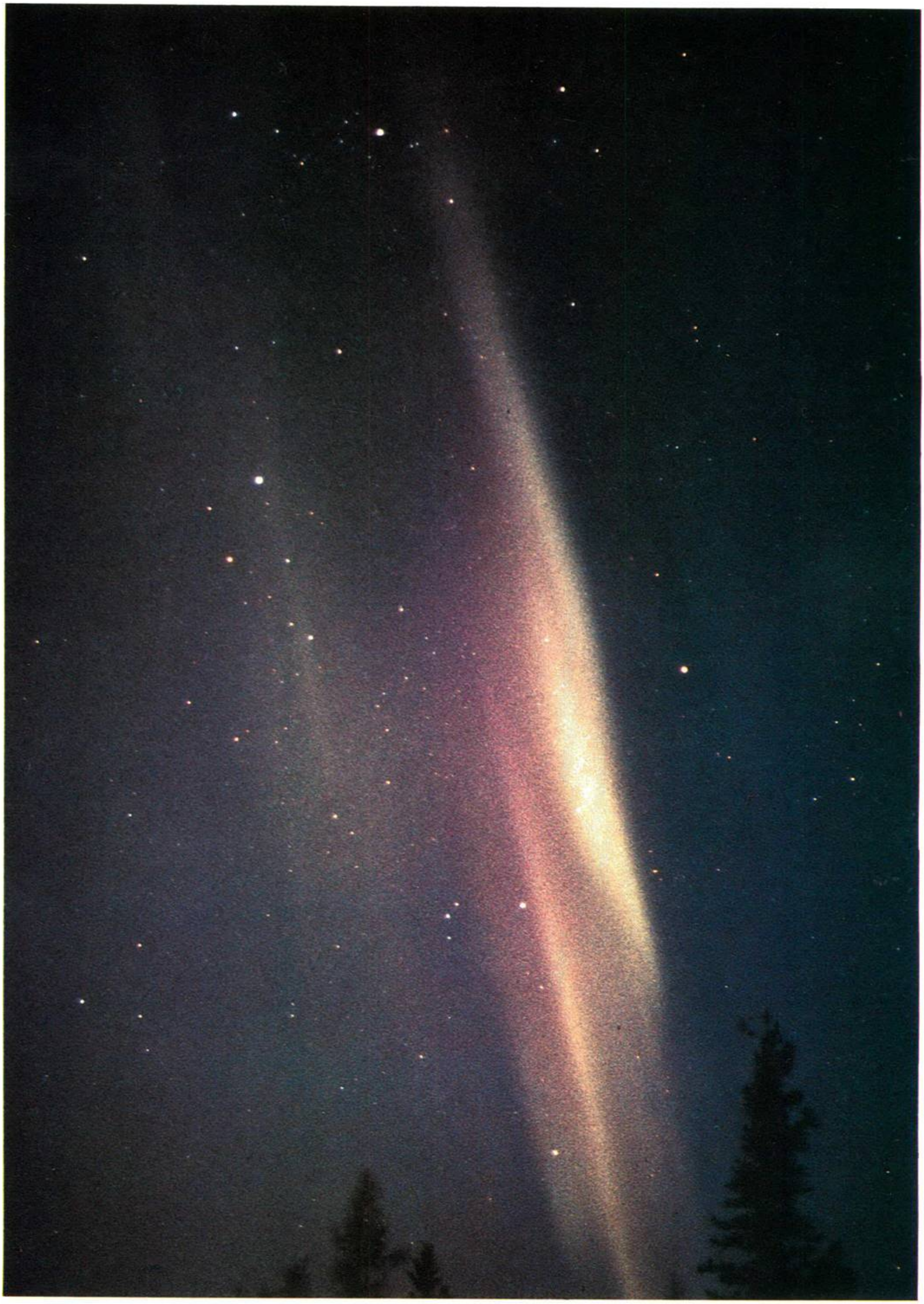
Neptune

To find Neptune, first locate Theta (θ) Ophiuchi. Then, having centered Theta in your eyepiece, scan directly north 3°. Neptune lies just to the west; if your eyepiece has a wide-field, you'll pick up the 8th magnitude planet as you scan. Look for a non-stellar disk 2.4 seconds of arc in diameter.

During the first few days of April 1980, Venus was passing to the south of the Pleiades. On April 1st, Fred Espenak caught the two in the same camera frame with his 500 mm lens. The exposure lasted 2 minutes at f/8 on 400 ASA slide film, which overexposed Venus, but was necessary to bring out the star cluster.

close-up on capricornus

Those who like to explore deep space — constellation by constellation, observing all the treasures of each one — will find this month's selection an easy project for an evening, for



Left: Samuel Powell, a reader in Fairbanks, Alaska, shot this aurora in March 1980. He used a 6-second exposure and a 50 mm lens. Above: The distinctive shape of Brocchi's Cluster (widely known as the Coathanger) lies in Vulpecula. Ron Gattie, of S. Plainfield, New Jersey, used a 200 mm lens and 100 ASA slide film.

Capricornus is rather lacking in objects of telescopic interest. Barns noted in his *1001 Celestial Wonders* that it "offers few highlights aside from its two superb doubles, recorded in ancient writ, and at least one surpassing cluster [M-30]."

Though well-known as a zodiacal constellation, Capricornus is also one of the dimmest, with only two stars brighter than fourth magnitude. The luminar of the constellation is **Delta** (δ) **Capricorni**, named **Deneb Algiedi**, at average magnitude 2.98. Deneb Algiedi is actually an eclipsing variable with a period of just over a day, but since the drop in magnitude is only 0.2, the eclipses will be almost impossible to observe. (According to the American Association of Variable Star Observers, Deneb Algiedi will be at minimum light at 10:00 p.m. C.D.T. on September 10, with minima occurring just over 33 minutes later on successive nights.) The calculated separation of the two components is only around a million miles.

The only other third magnitude star is **Beta** (β), also called **Dabih**, at 3.25. Dabih is one of Barns' "two superb doubles," although in reality it is a common proper motion pair consisting of a spectroscopic triple (Beta A) and a close double (Beta B). The two main components are separated by an easy 3½ minutes of arc at position angle 267° — almost exactly east-west in the sky. The primary, Beta A, looks yellowish, agreeing well with its spectral type of G0, while its companion, an A0 star, has a contrasting clear blue-white cast.

A large telescope and good observing conditions will reveal Beta B to consist of two components of magnitudes 6.2 and 10.0 separated by less than one arc-second in position angle 89° — also east-west on the sky. Can you split this difficult pair?

Alpha (α) **Capricorni**, or **Al Giedi** (which means "the Goat"), is a wide optical double, separated by more than six arc-minutes and consisting of magnitude 3.5 and 4.2 components, each of which is itself a multiple system. Lying roughly east-west on the sky, both **Alpha^1** and **Alpha^2** have an unmistakable yellowish-orange cast — their spectral types are G5 and G8 respectively. Together they are a superb sight in binoculars and telescopes at low power.

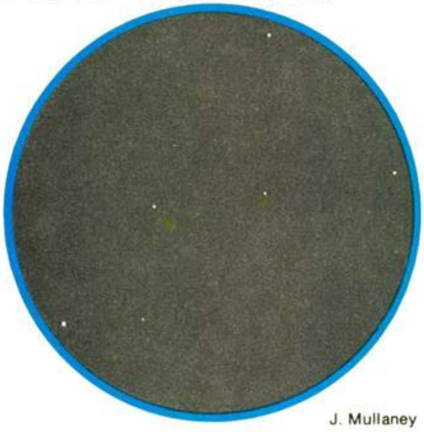
But this is not the system's sole attraction, for Al Giedi as seen through the eyepiece becomes a striking double-double. Alpha^1 has a ninth magnitude companion 46 seconds distant at position angle 221°, while Alpha^2's companion shines at magnitude 10.6, seven seconds away and nearly north-south on the sky.

But there is still more, for large amateur instruments will reveal Alpha^2 to be a triple system. The dimmer 10.6 magnitude component actually consists of two eleventh-magnitude stars separated by only 1.2" (at position angle 238°). Splitting this close pair is considered a test for a six-inch aperture, and requires both good seeing (image steadiness) and transparency (atmospheric clarity). Can you do it with your scope?

Al Giedi may not be quite the showpiece that Epsilon (ϵ) Lyrae, the most famous "double-double," is, but it has a distinct charm all its own. Try comparing the two some September evening.

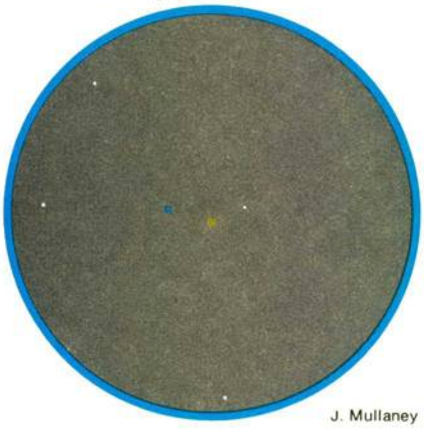
Two pleasing and easy doubles complete our list of Capricornus' multiple stars. The first of these, **Pi** (π) **Capricorni**, consists of fifth and ninth magnitude stars separated by 3.2" at position angle 148°. The other, **Omicron** (o) **Capricorni**, is a more

Alpha Capricorni



J. Mullaney

Beta Capricorni



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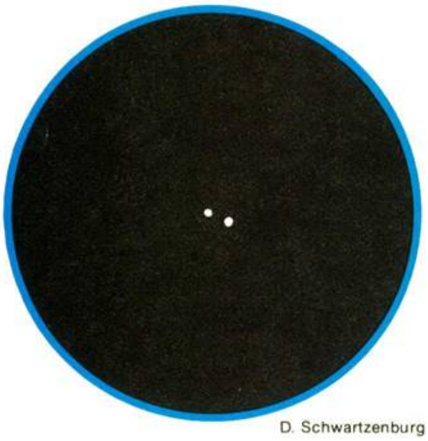
Omicron Capricorni



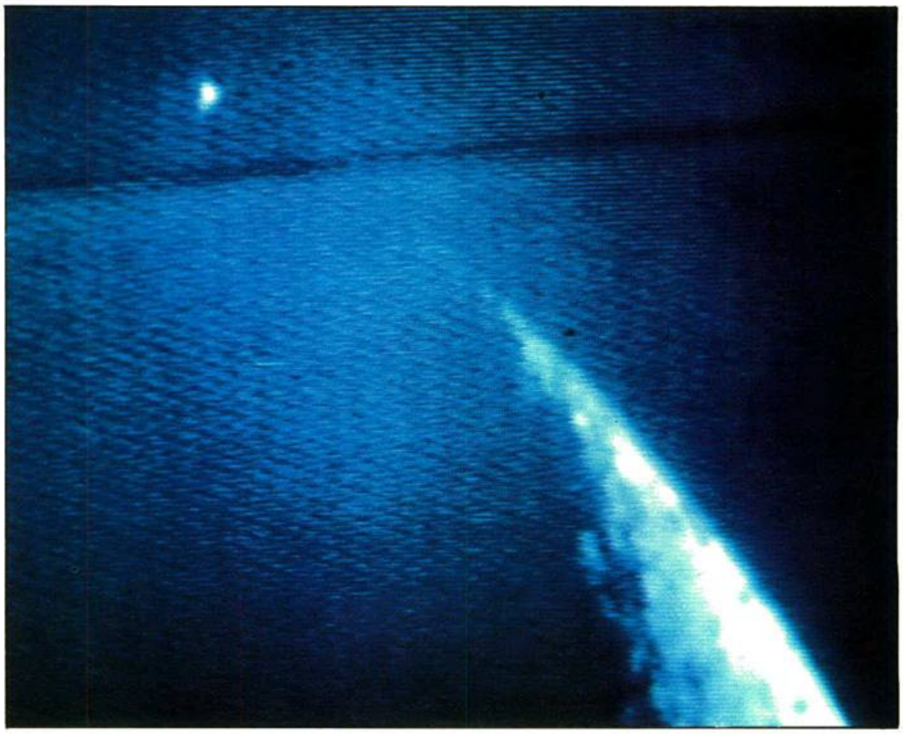
D. Schwartzenburg

closely matched pair of 6.1 and 6.6 magnitude suns at a distance of 22" (position angle 239°). Try comparing the appearance of these two doubles in your telescope.

RR Capricorni, a long-period Mira-type variable, is currently fading from its maximum, which occurred in June. Try looking for it early in the month, for by the beginning of October it will have faded below magnitude 13.5.

The "surpassing cluster" mentioned by Barns is **M-30**, a globular cluster situated about seven degrees south of Delta, very near the fifth magnitude star 41 Capricorni. Webb described it as "moderately bright; beautifully contrasted with an eighth magnitude star beside it; cometlike with 64 [power]; with higher powers resolvable." This observation was made with a 3.7-inch refractor from the latitude of England.

M-30 is listed in catalogs (and in our table) as being six minutes of arc in diameter and shining at magnitude 8.2. Some sources, however, consider this object to be at least a magnitude brighter than this. How do you find it?



The Pontchartrain Astronomy Society (of New Orleans) helped a local TV station broadcast the June 17, 1980 grazing occultation of Regulus by hooking up a b&w TV camera to the eyepiece of a C-8. This shot, taken by Norman Jacobs, shows what viewers saw later that night on the 10 p.m. news.

observers' reports

From Chuck Coates: Do not despair if you look at M-51 and do not see it well at first. Keep seeking it out from different observing sites, and come back to it time and again. It's not really a very "easy" object. During the early morning hours in February this year, I finally obtained some satisfactory views of it with instruments up to 12" and magnifications up to 160x. With such telescopes, it shows its structure well.

The galaxy appears bright across its entire face. On that glow I could see two definite spiral arms. The western one looked brighter, and, in places, seemed to be broken, and also did not seem to attach directly to the central small bright hub. Other people say they can see one and a half turns of the arms, but I cannot. Nor could I see the arm that appears to connect M-51 to its companion galaxy. The companion, an oval-shaped glob, appears quite bright, and under good conditions a fine texture may be seen on its western side.

From Matt Penn: Satellite passages through telescopic fields of view seem to be pretty common, and are easily observed by any amateur astronomer. In September 1978, I observed 14 satellites in three observing sessions lasting about one hour each. Although I used no optical equipment for the detection of objects, I followed them in 7 x 50 binoculars.

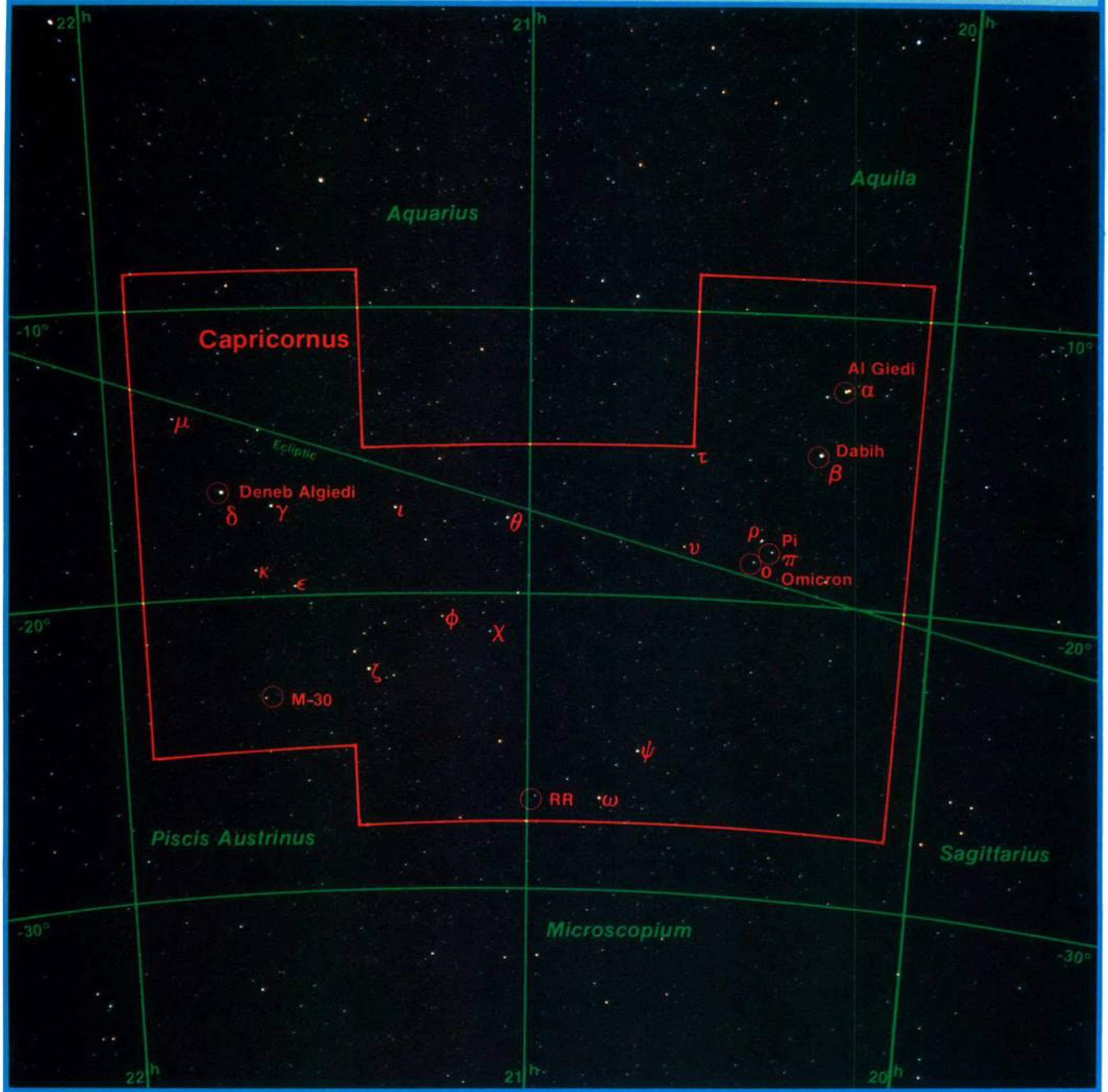
Early summer to early autumn seems to be the best time for observing these objects, possibly because of the late twilight. I usually lie flat on the ground. I try to concentrate on a star near the zenith, while staying aware of the stars surrounding it, watching for any movement. It helps to try to stay as still as possible. If you move around much, detection is harder. After looking for five to seven minutes, I find that a short rest and switching to another star prevents fatigue.

After you've found one, and have the technique down, other satellites will come easier. Sometimes it's very surprising to find a satellite, since they "pop" into view. A large number of satellites blink on and off as they move across the sky, due to their rotation. I guess that satellite observing isn't very popular among most amateur astronomers, but most people who try it find it's fun.

Map by Dewey Schwartzenburg

capricornus

Photo by R. Provin & B. Wallis


22h
21h
20h
Aquarius
Aquila
-10°
-10°
Capricornus
Al Giedi
α
μ
Ecliptic
τ
Dabih
β
Deneb Algiedi
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Omicron
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-20°
-20°
φ
χ
ζ
M-30
ψ
RR
ω
Piscis Austrinus
Sagittarius
-30°
-30°
Microscopium
22h
21h
20h

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (1980)	Dec.
Alpha (α^1)	★^{2}	4.5,9.0	46″	20^h15^m	-12°40′	20^h17^m	-12°34′
Alpha (α^2)	★^{3}	3.8,11.2,11.5	7″,1.2″	20^h15^m	-12°42′	20^h17^m	-12°36′
Beta (β)	★^{3}	3.2,6.2,10.0	205″,0.9″	20^h18^m	-14°56′	20^h20^m	-14°51′
Pi (π)	★^{2}	5.2,8.5	3.2″	20^h24^m	-18°23′	20^h26^m	-18°17′
Omicron (o)	★^{2}	6.1,6.6	22″	20^h27^m	-18°45′	20^h29^m	-18°39′
RR	m★	7.8-14.5	277^d	20^h59^m	-27°17′	21^h01^m	-27°10′
M-30	●	8.2	6′	21^h38^m	-23°25′	21^h40^m	-23°17′
Delta (δ)	Ӿ★	2.9-3.1	1.023^d	21^h44^m	-16°21′	21^h46^m	-16°14′

★	*Star*
★^{2}	*Double Star*
★^{3}	*Triple Star*
m★	*Regular Variable*
∩★	*Irregular Variable*
Ӿ★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*

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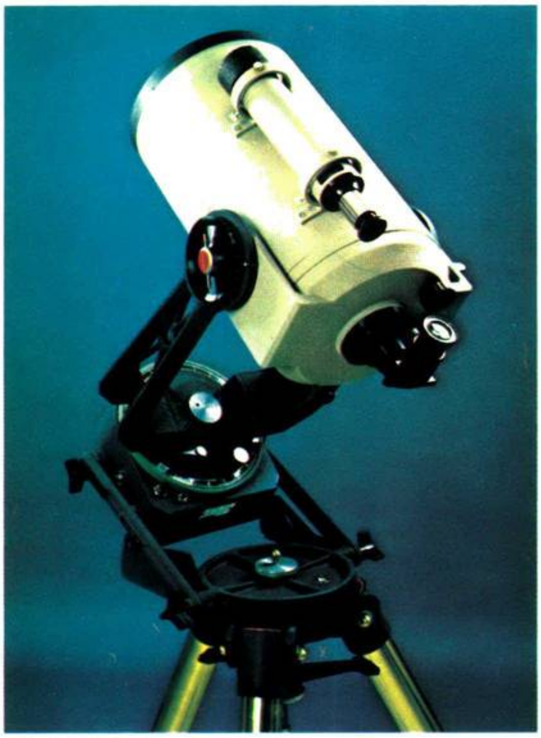

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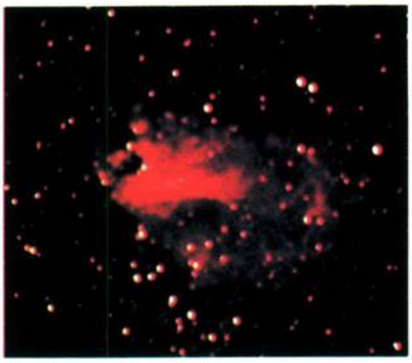

The Omega Nebula (M17) as photographed through the Dynamax 8.

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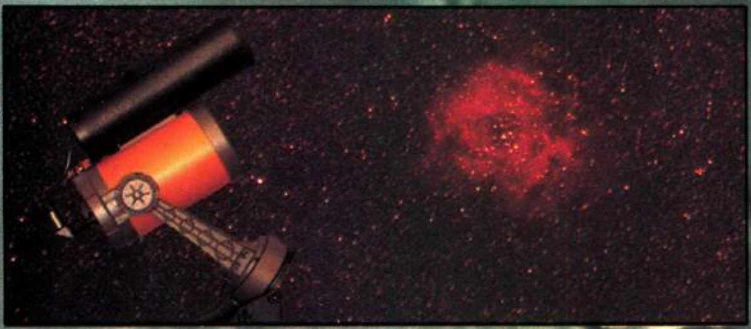

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